

SCXML

State Chart XML

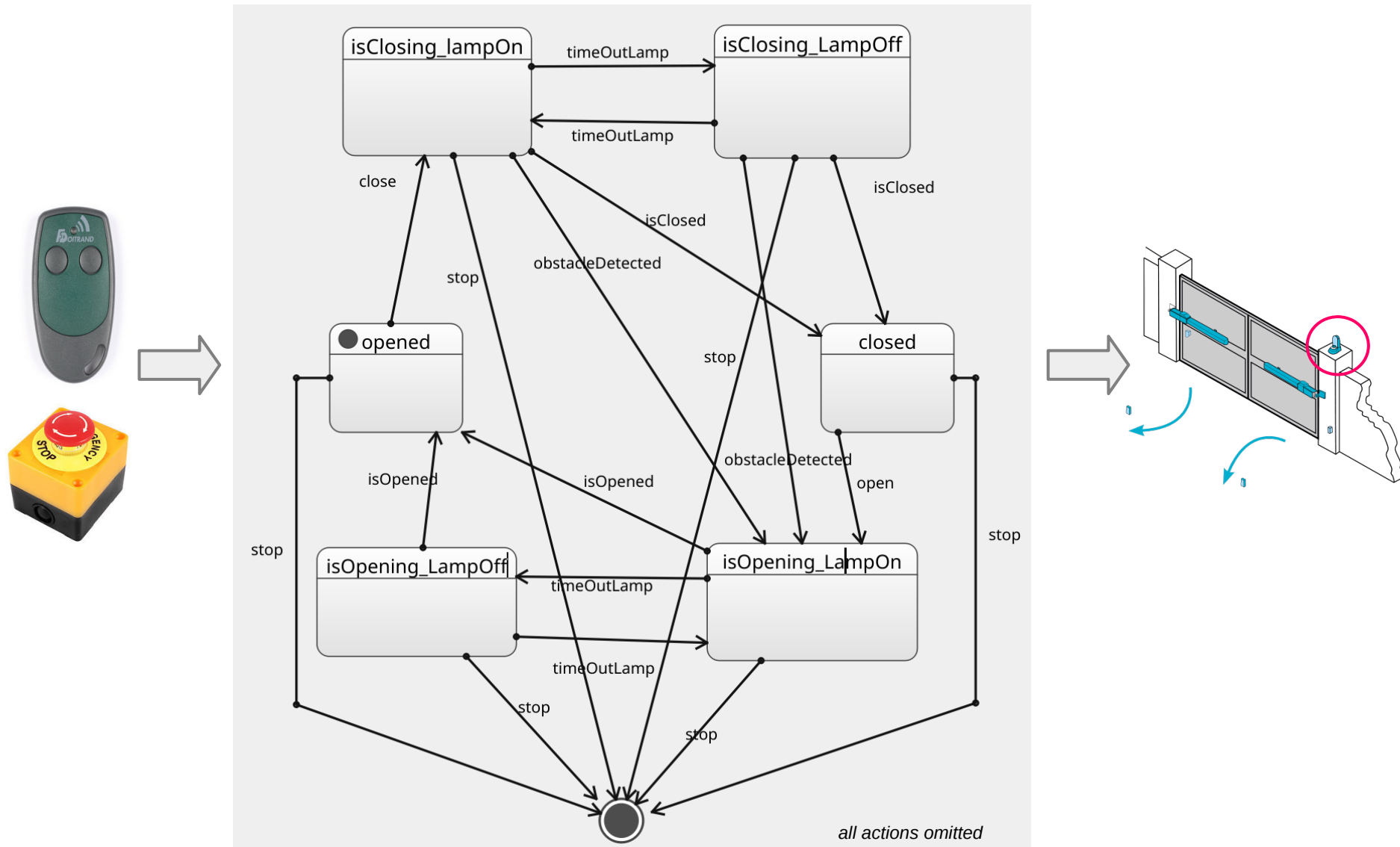
Previously, in this course...

Previously, in this course...

Running Example

statecharts = state-diagrams + depth

+ orthogonality + broadcast-communication.



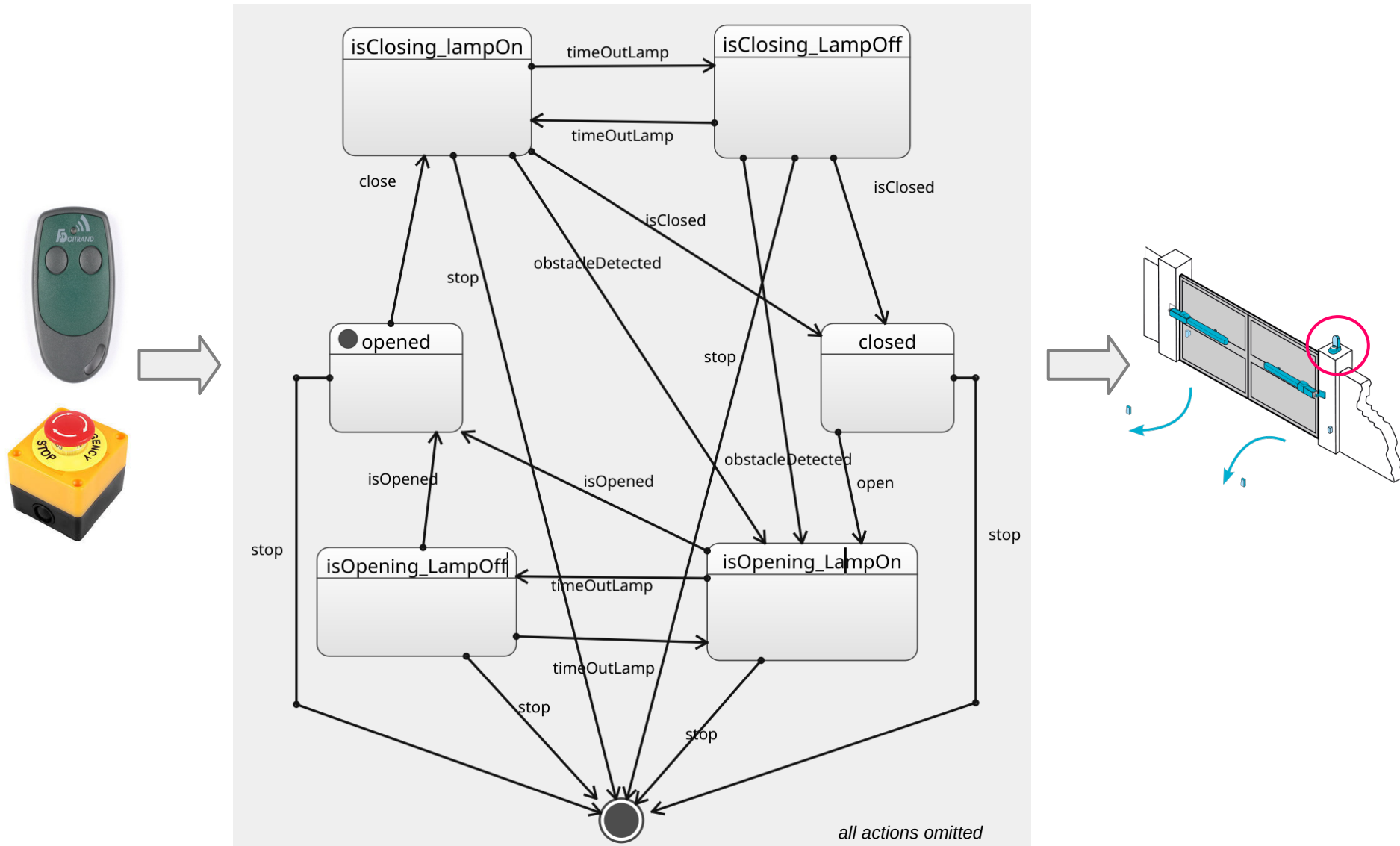
wasn't it supposed to help ?

Previously, in this course...

Running Example

statecharts = state-diagrams + depth

+ orthogonality + broadcast-communication.



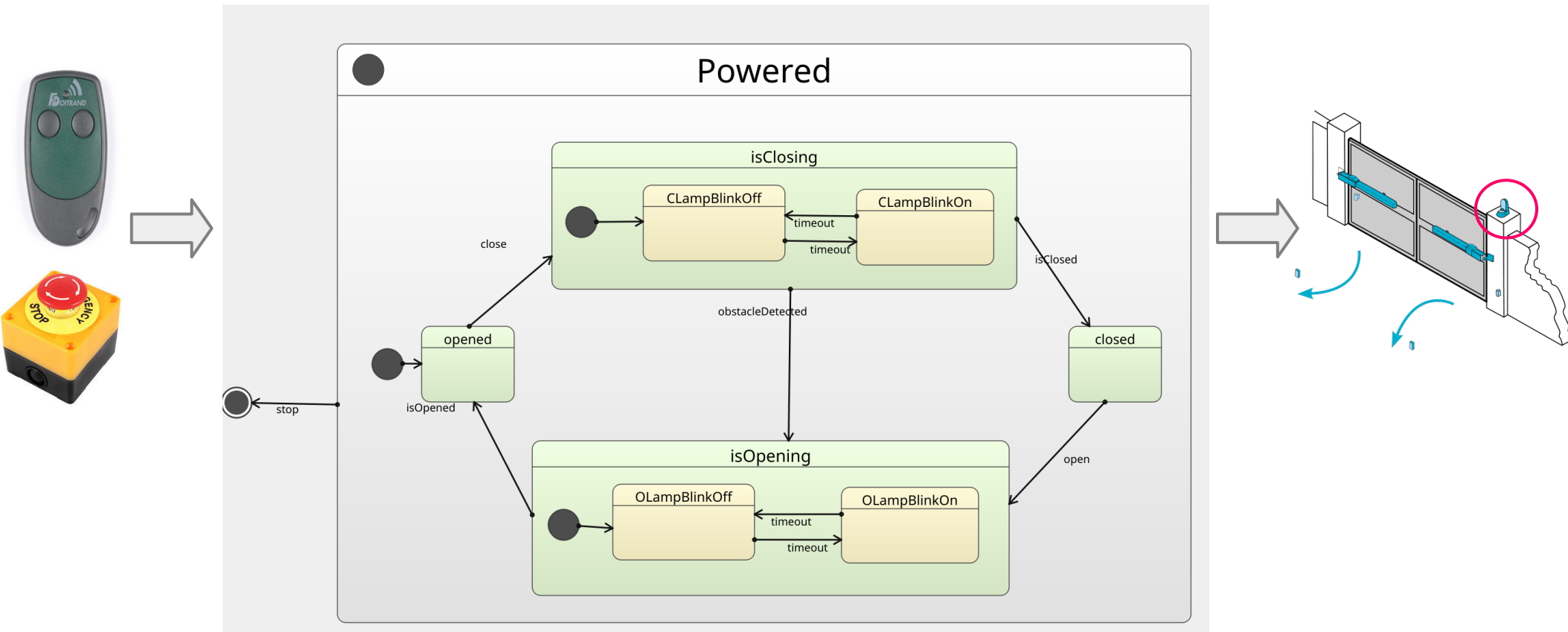
- Substates may be nested to any level. A nested state machine may have at most one initial state and one final state.
- **Substates are used to simplify complex flat state machines by showing that some states are only possible within a particular context (the enclosing state).**
- A composite state factorizes the possible exits from all (most of) the states

Previously, in this course...

Running Example

statecharts = state-diagrams + depth

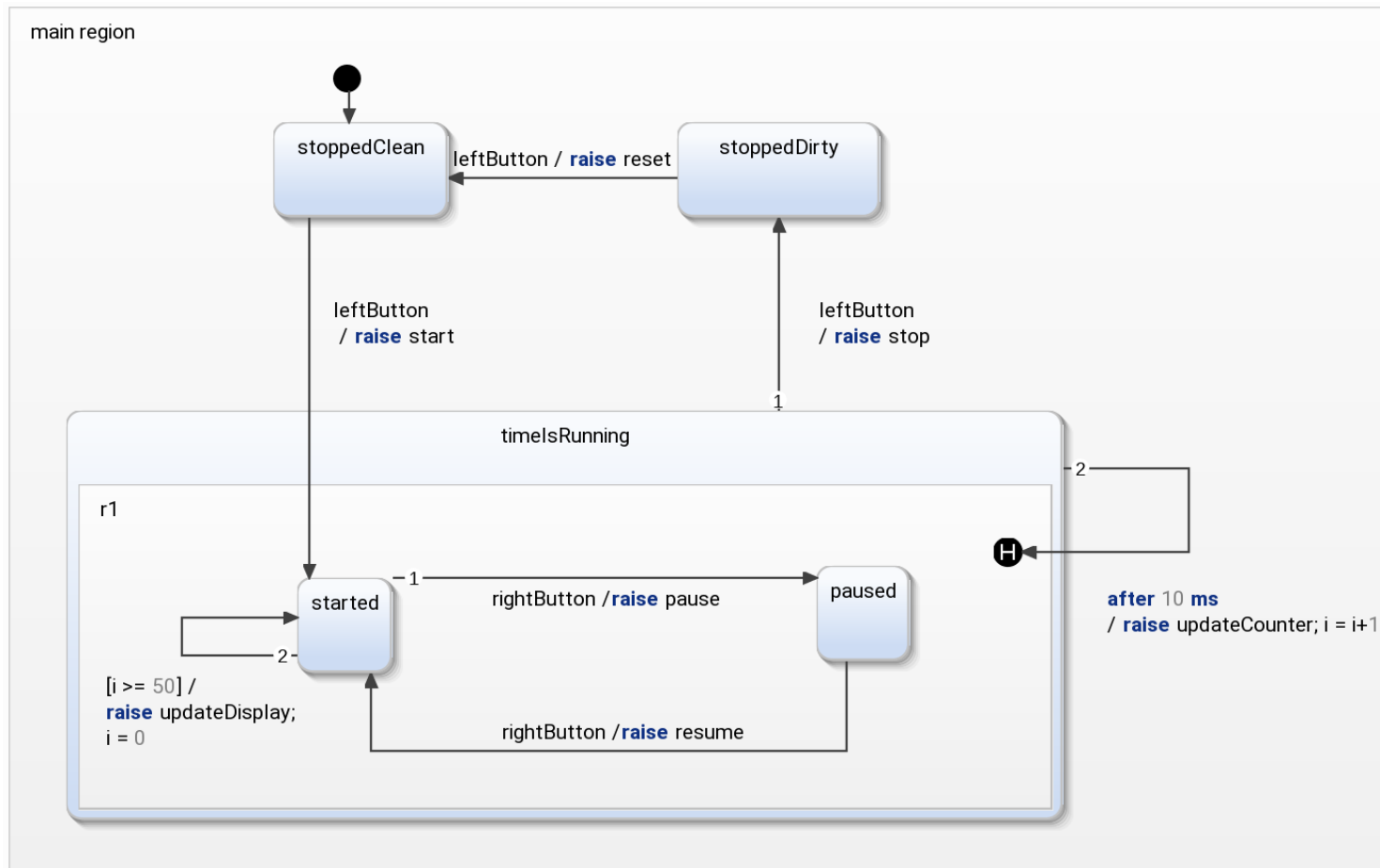
+ orthogonality + broadcast-communication.



all actions omitted

- A simple state is one which has no substructure.
- A state which has substates (nested states) is called a composite state (or compound state).
- Substates may be nested to any level. A nested state machine may have at most one initial state and one final state.
- **Substates are used to simplify complex flat state machines by showing that some states are only possible within a particular context (the enclosing state).**
- **A composite state factorizes the possible exits from all (most of) the states**

Stopwatch

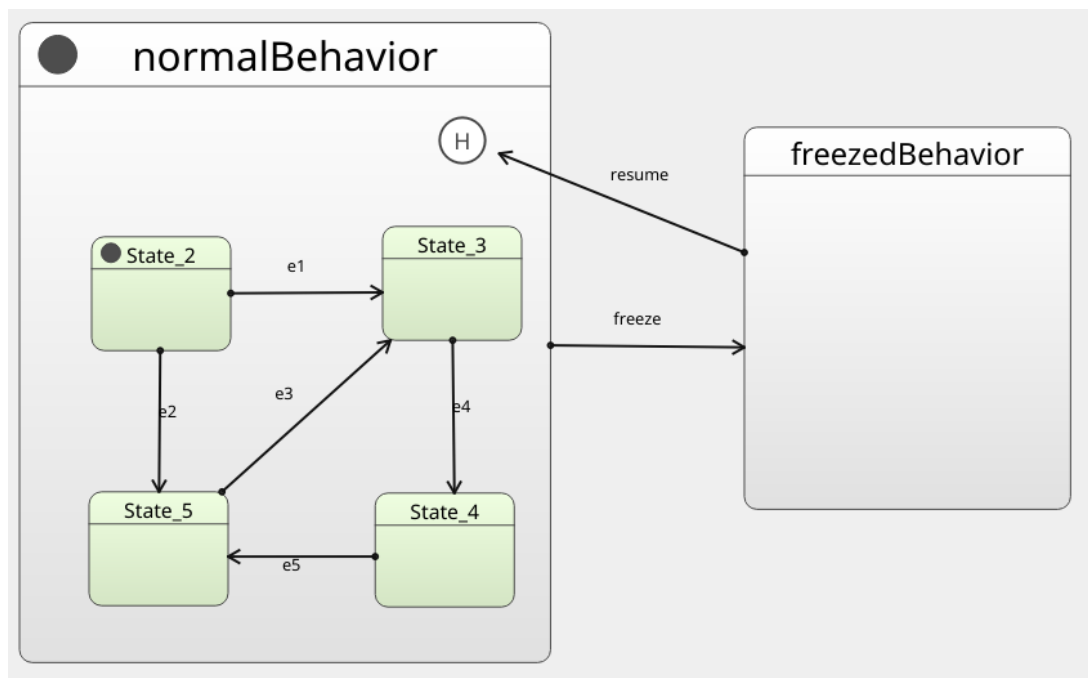


- A simple state is one which has no substructure.
- A state which has substates (nested states) is called a composite state (or compound state).
- Substates may be nested to any level. A nested state machine may have at most one initial state and one final state.
- **Substates are used to simplify complex flat state machines by showing that some states are only possible within a particular context (the enclosing state).**
- **A composite state factorizes the possible exits from all (most of) the states**

Taken and modified from http://sce.uhcl.edu/helm/rationalunifiedprocess/process/modguide/md_stadm.htm

History state

Deep or shallow...



- **<history> allows for pause and resume semantics in compound states.** Before the state machine exits a compound state, it records the state's active descendants. If the 'type' attribute of the <history> state is set to "deep", the state machine saves the state's full active descendant configuration, down to the atomic descendant(s). If 'type' is set to "shallow", the state machine remembers only which immediate child was active. After that, if a transition takes a <history> child of the state as its target, the state machine re-enters not only the parent compound state but also the state(s) in the saved configuration. Thus a transition with a deep history state as its target returns to exactly where the state was when it was last exited, while a transition with a shallow history state as a target re-enters the previously active child state, but will enter the child's default initial state (if the child is itself compound.).

TD stopWatch

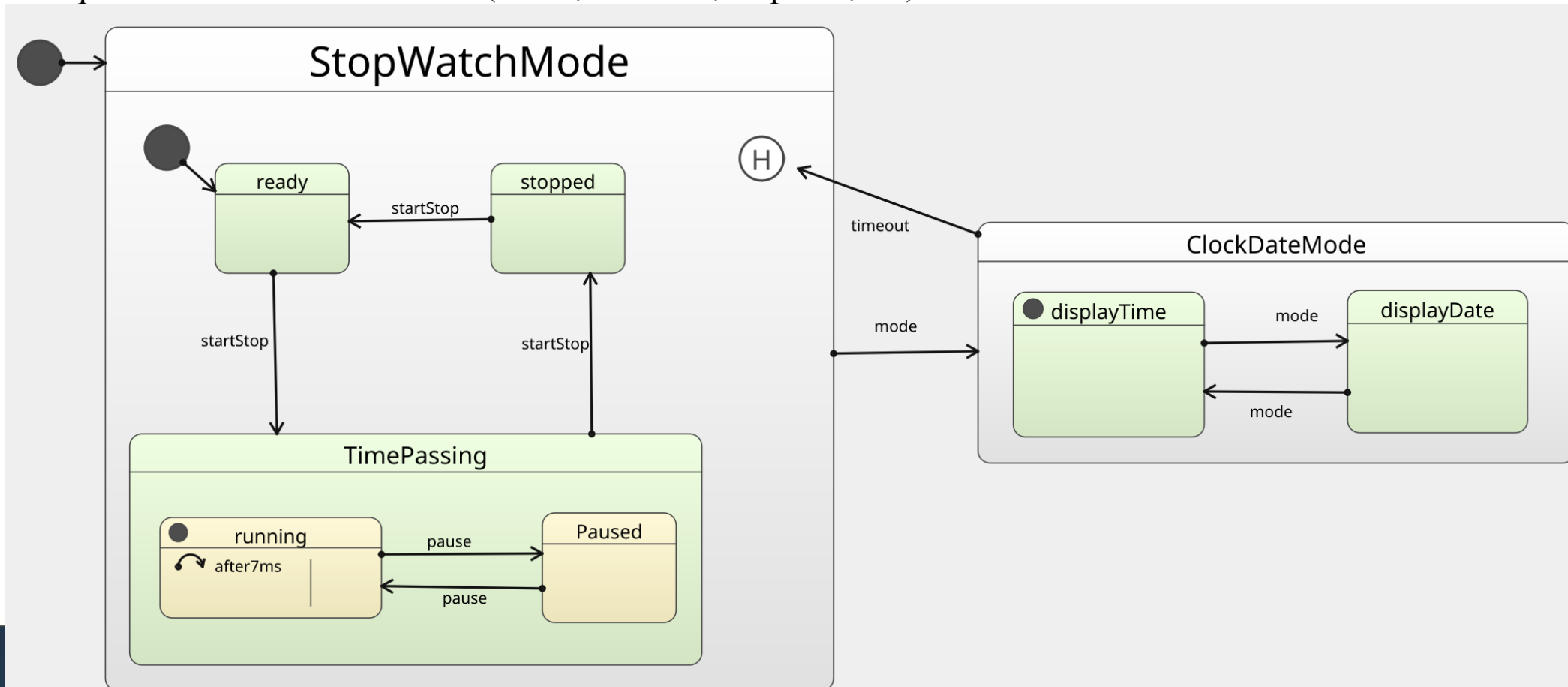
Version 3

Vous allez ajouter du comportement à la version 2. Il s'agit ici d'ajouter un troisième bouton "mode". Ce bouton permet d'afficher l'heure ou la date pendant 1 seconde. Au premier appuie sur le bouton, l'affichage devra montrer l'heure courante. Au bout d'une seconde, si le bouton n'a pas été appuyé à nouveau, le chronomètre retourne dans l'état où il était. Si le bouton est appuyé à nouveau avant 1 seconde, l'affichage montrera la date. De même, si aucun bouton n'est appuyé pendant 1 seconde on retourne au comportement initial, sinon on remontre l'heure courante. Le fonctionnement décrit sera actif peu importe l'état dans lequel se trouve le chronomètre (arrêté, démarré, en pause, etc).

TD stopWatch

Version 3

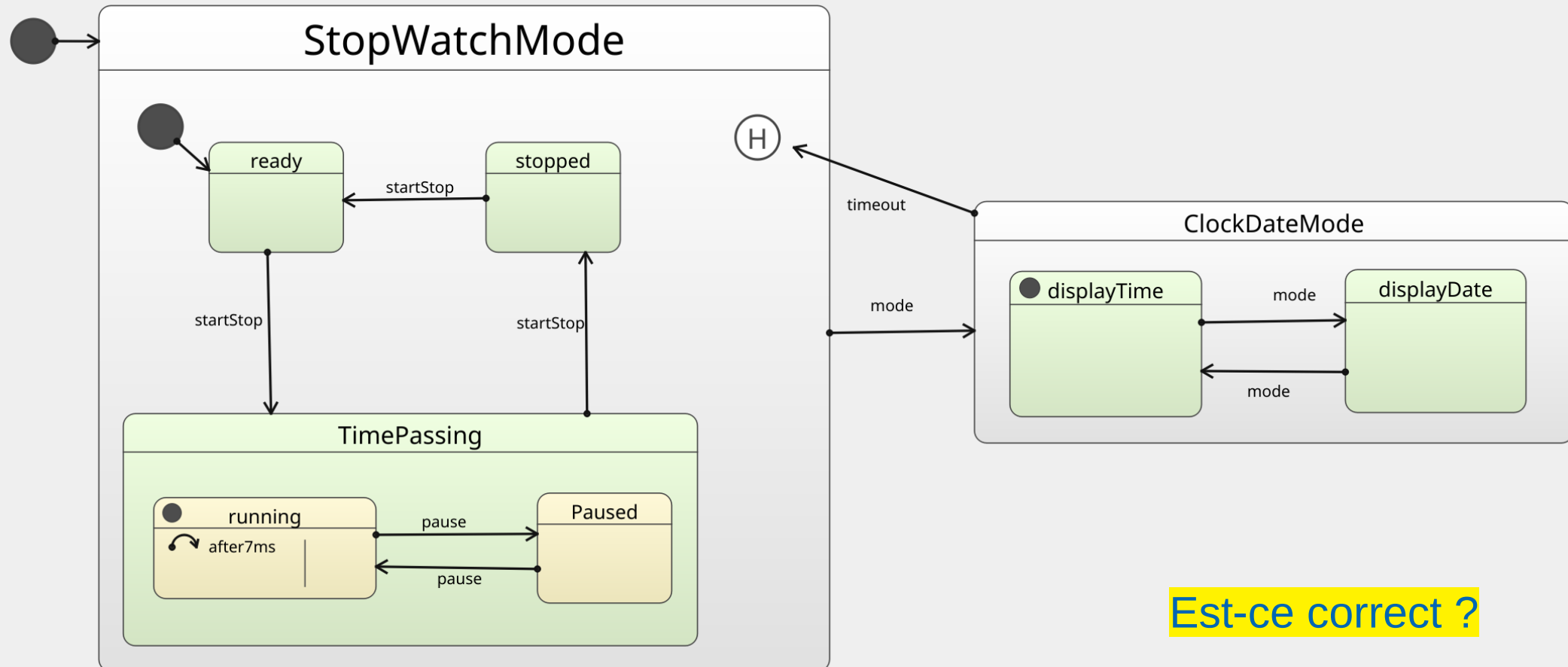
Vous allez ajouter du comportement à la version 2. Il s'agit ici d'ajouter un troisième bouton "mode". Ce bouton permet d'afficher l'heure ou la date pendant 1 seconde. Au premier appuie sur le bouton, l'affichage devra montrer l'heure courante. Au bout d'une seconde, si le bouton n'a pas été appuyé à nouveau, le chronomètre retourne dans l'état où il était. Si le bouton est appuyé à nouveau avant 1 seconde, l'affichage montrera la date. De même, si aucun bouton n'est appuyé pendant 1 seconde on retourne au comportement initial, sinon on remontre l'heure courante. Le fonctionnement décrit sera actif peu importe l'état dans lequel se trouve le chronomètre (arrêté, démarré, en pause, etc).



TD stopWatch

Version 3

Vous allez ajouter du comportement à la version 2. Il s'agit ici d'ajouter un troisième bouton "mode". Ce bouton permet d'afficher l'heure ou la date pendant 1 seconde. Au premier appuie sur le bouton, l'affichage devra montrer l'heure courante. Au bout d'une seconde, si le bouton n'a pas été appuyé à nouveau, le chronomètre retourne dans l'état où il était. Si le bouton est appuyé à nouveau avant 1 seconde, l'affichage montrera la date. De même, si aucun bouton n'est appuyé pendant 1 seconde on retourne au comportement initial, sinon on remontre l'heure courante. Le fonctionnement décrit sera actif peu importe l'état dans lequel se trouve le chronomètre (arrêté, démarré, en pause, etc).

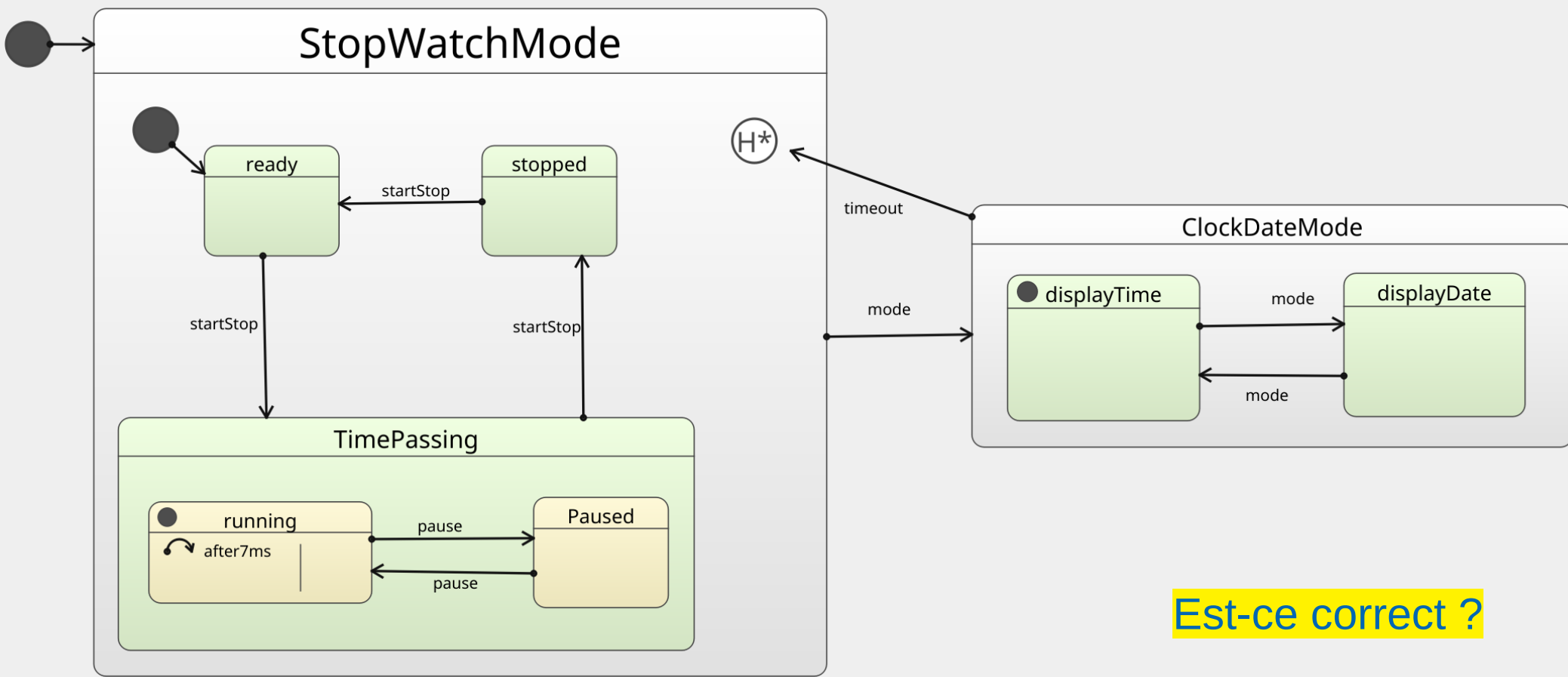


Est-ce correct ?

TD stopWatch

Version 3

Vous allez ajouter du comportement à la version 2. Il s'agit ici d'ajouter un troisième bouton "mode". Ce bouton permet d'afficher l'heure ou la date pendant 1 seconde. Au premier appuie sur le bouton, l'affichage devra montrer l'heure courante. Au bout d'une seconde, si le bouton n'a pas été appuyé à nouveau, le chronomètre retourne dans l'état où il était. Si le bouton est appuyé à nouveau avant 1 seconde, l'affichage montrera la date. De même, si aucun bouton n'est appuyé pendant 1 seconde on retourne au comportement initial, sinon on remonte l'heure courante. Le fonctionnement décrit sera actif peu importe l'état dans lequel se trouve le chronomètre (arrêté, démarré, en pause, etc).



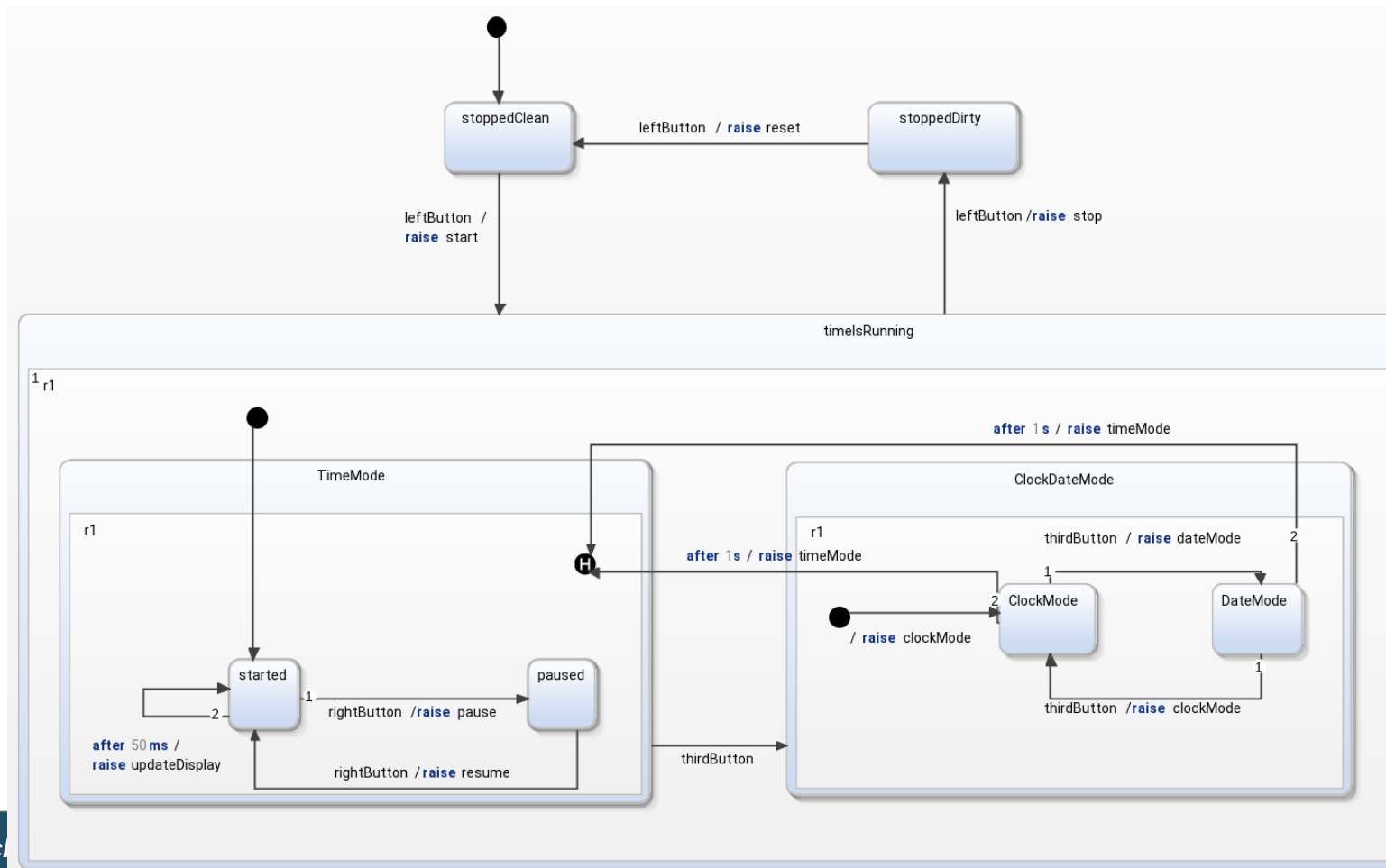
Est-ce correct ?

TD stopWatch and hierarchy !

Version 3

revisited

Vous allez ajouter du comportement à la version 2. Il s'agit ici d'ajouter un troisième bouton "mode". Ce bouton permet d'afficher l'heure ou la date pendant 1 seconde. Au premier appuie sur le bouton, l'affichage devra montrer l'heure courante. Au bout d'une seconde, si le bouton n'a pas été appuyé à nouveau, le chronomètre retourne dans l'état où il était. Si le bouton est appuyé à nouveau avant 1 seconde, l'affichage montrera la date. De même, si aucun bouton n'est appuyé pendant 1 seconde on retourne au comportement initial, sinon on remontre l'heure courante. Le fonctionnement décrit sera actif peu importe l'état dans lequel se trouve le chronomètre (arrêté, démarré, en pause, etc).



SCXML

State Chart XML

Parallel regions, communications
and a little bit more

State Charts

statecharts = state-diagrams + depth

+ orthogonality + broadcast-communication.

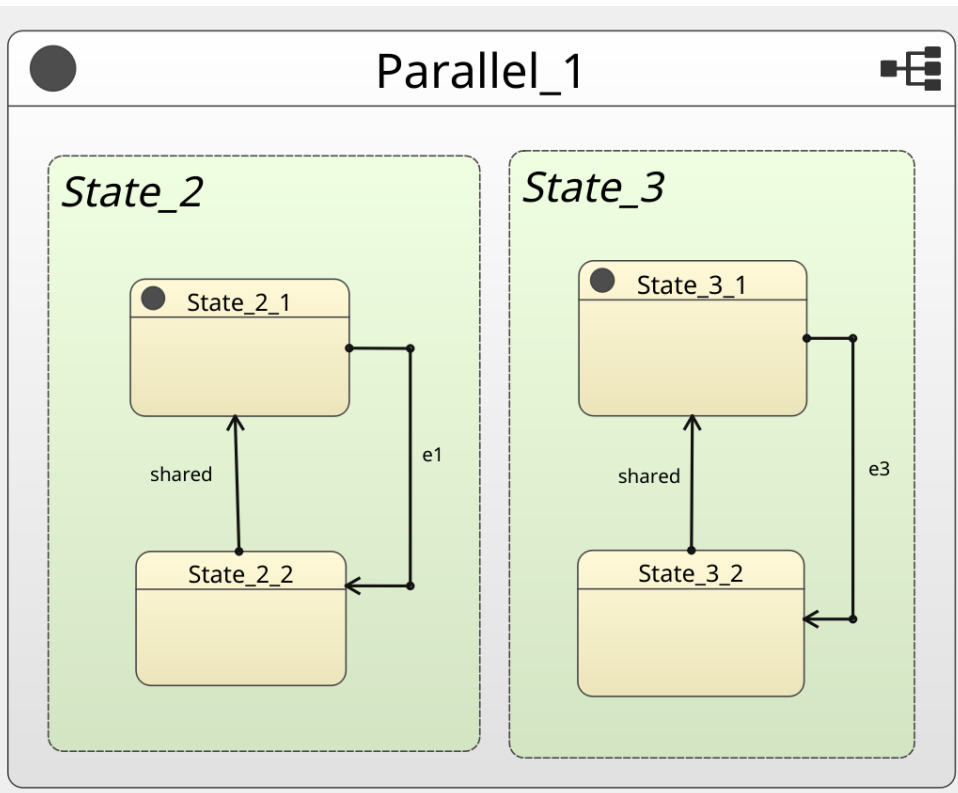
David Harel

Statecharts: A visual formalism for complex systems

Science of computer programming 8 (3), 231-274

1987

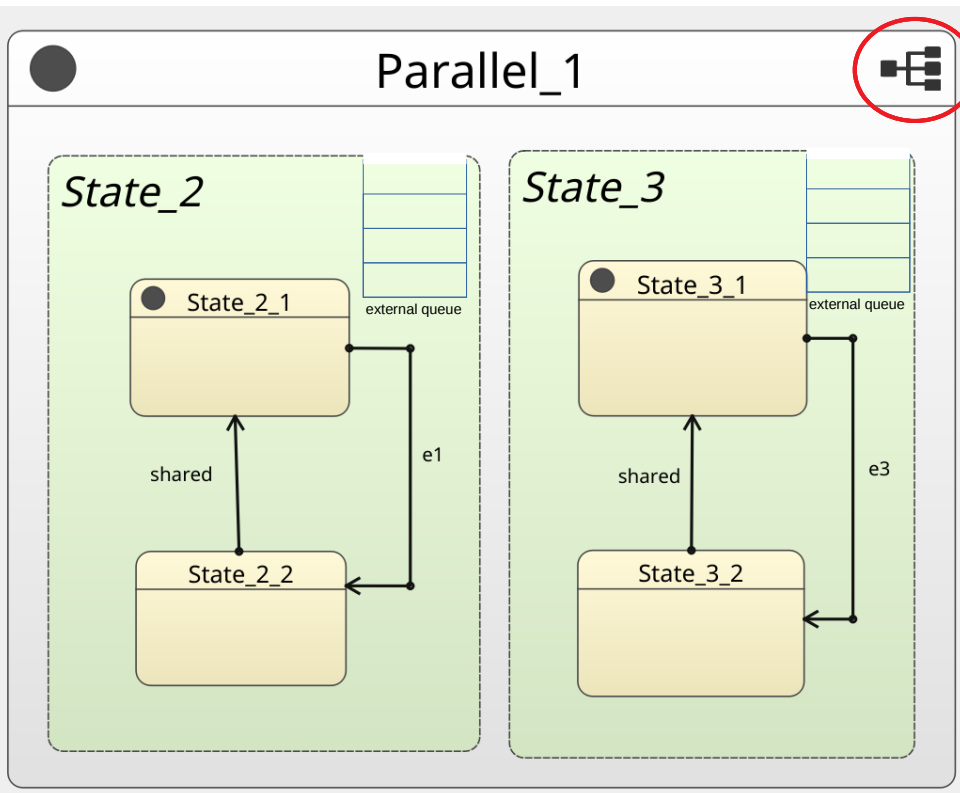
Parallel states



Also named Orthogonal regions in UML or AND-States (Since after initialization, the machine is in substate *State_2_1* AND *State_3_1*.)

Everything is working as if *State_2* and *State_3* were independent. When the machine is in a parallel state, all event received are broadcasted to all the parallel states. They can consume them or not like any normal state machine

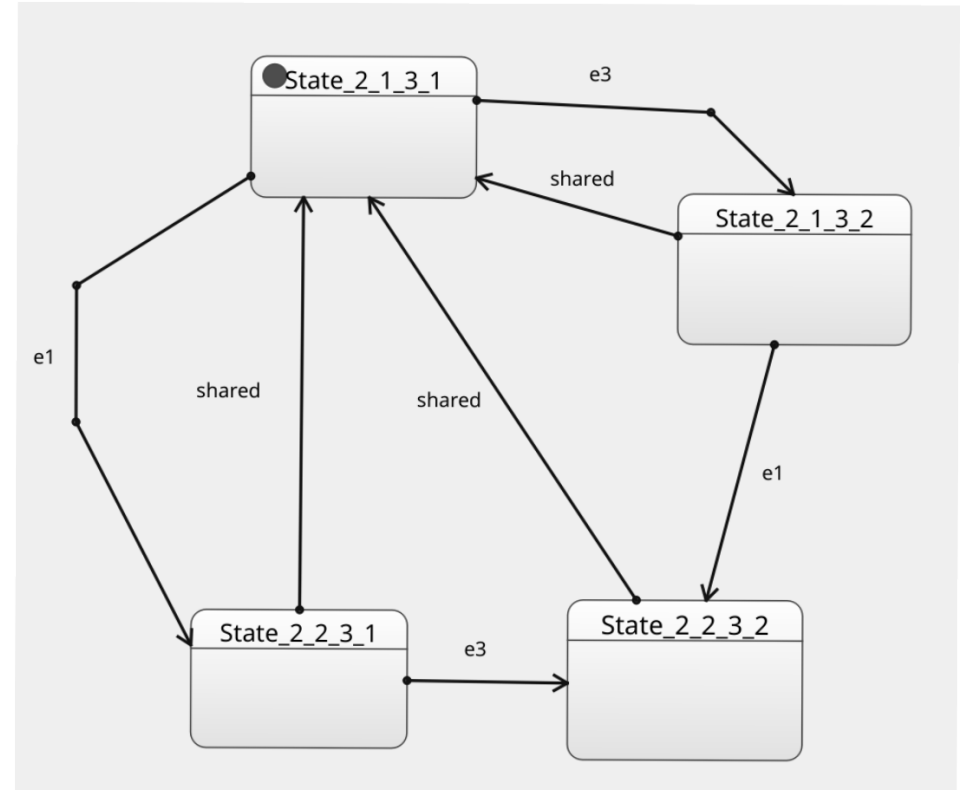
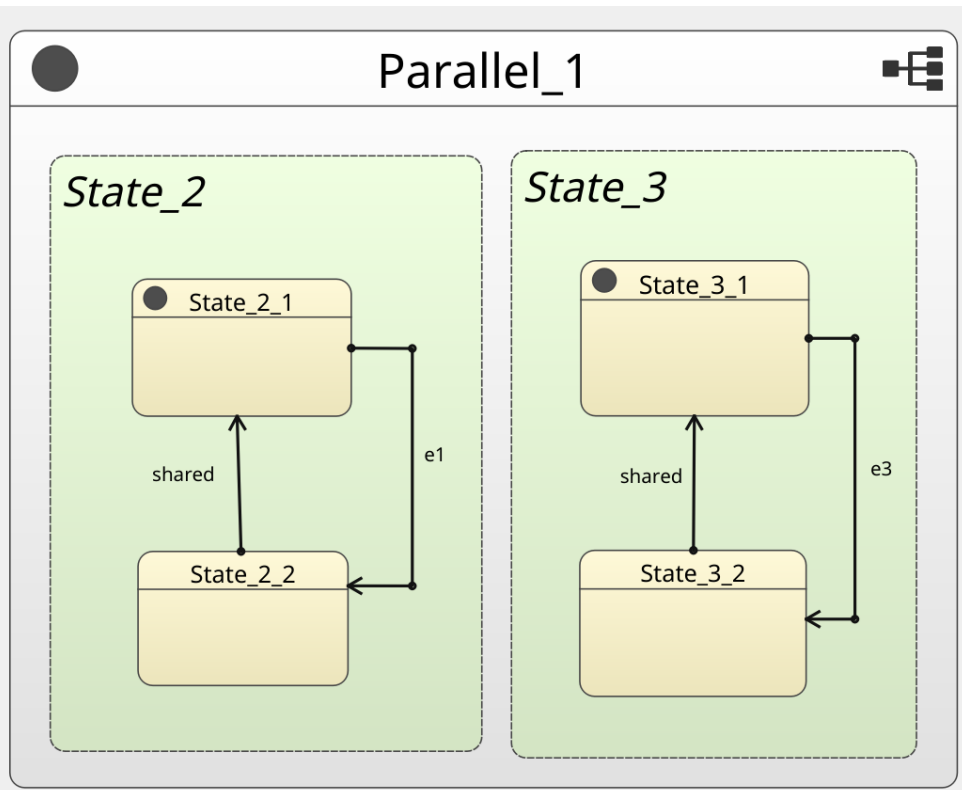
Parallel states



Also named Orthogonal regions in UML or AND-States (Since after initialization, the machine is in substate *State_2_1* AND *State_3_1*.)

Everything is working as if *State_2* and *State_3* were independent. When the machine is in a parallel state, all event received are broadcasted to all the parallel states. They can consume them or not like any normal state machine

Parallel states



The Cartesian product of the states allows for “sequential” equivalence of the input language but warning about the actions, *i.e.*, the behavior of the system !!

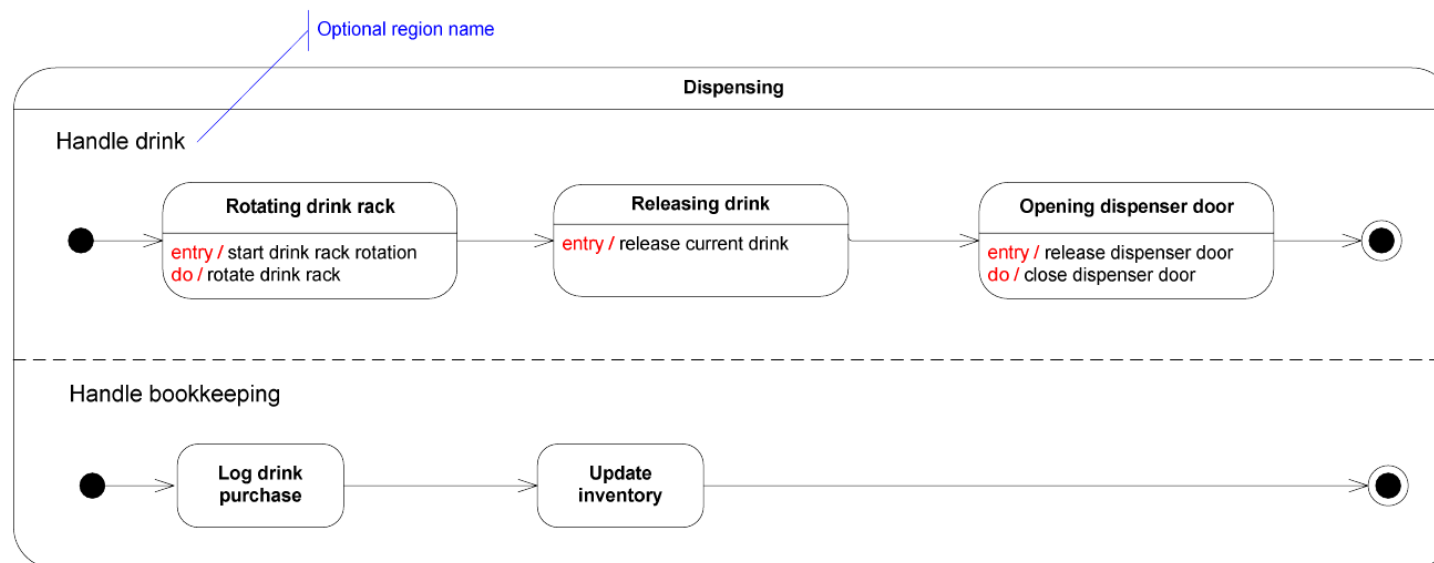
By using parallel states, the complexity in number of state is the sum of the number of states in each parallel states while otherwise it is the product of them
(if we add another parallel state with 3 states, the “sequential” result have 12 states)

Parallel states

Other representations and naming: UML

Composite states / regions

- Each region within a composite state **executes in parallel**.
- A transition to the final state of a region indicates **completing the activity for that region**.
- Once all the regions have completed, the composite state triggers a **completion event** and a **completion transition** (if one exists) triggers.



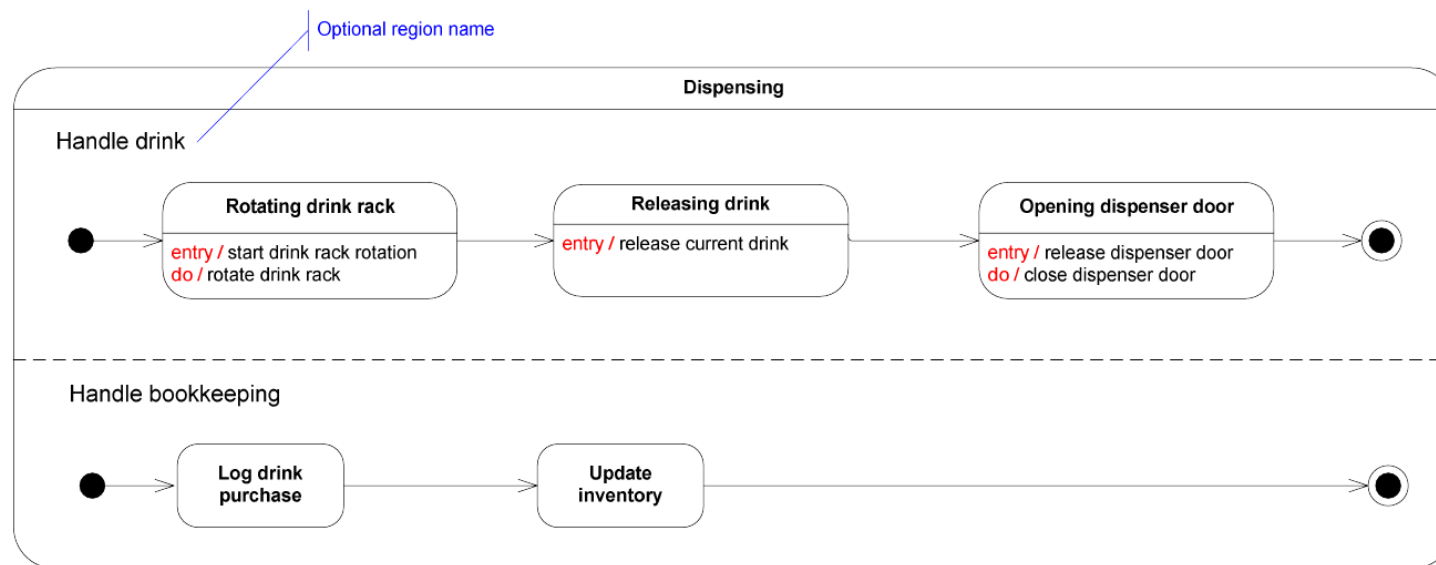
Composite state with two regions

From Charles André's slides

Other representations and naming: UML

Composite states / regions

- Each region within a composite state **executes in parallel**.
- A transition to the final state of a region indicates **completing the activity for that region**.
- Once all the regions have completed, the composite state triggers a **completion event** and a **completion transition** (if one exists) triggers.



Composite state with two regions

From Charles André's slides



UML syntax is more complex than scxml since no reuse is done (e.g., about the datamodel)

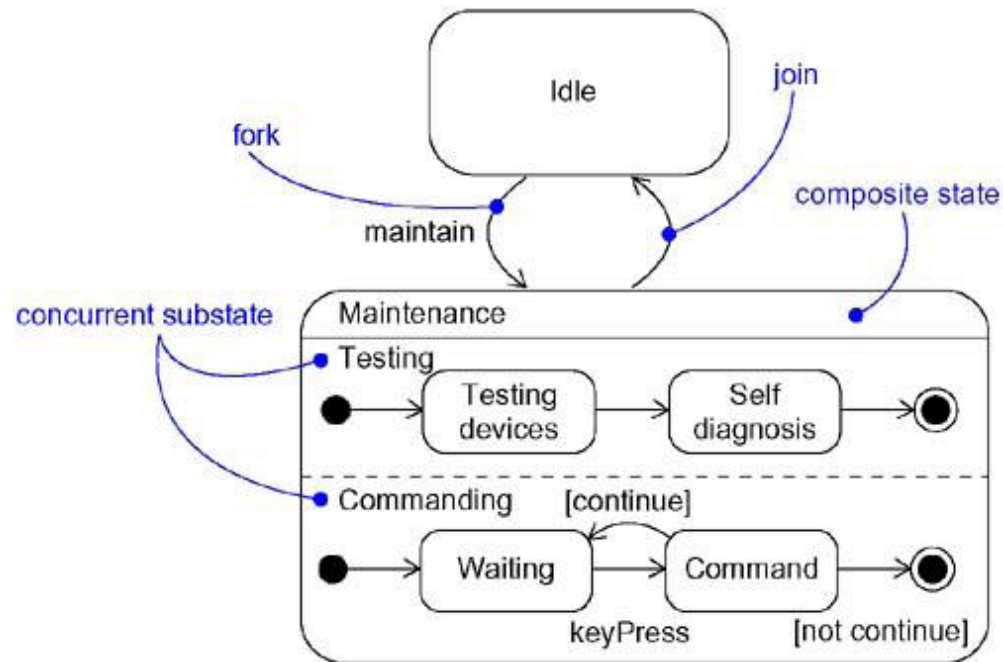
Parallel states

Yet another representation and naming

concurrent substates specify two or more state machines that execute in parallel in the context of the enclosing object

Execution of these concurrent substates continues in parallel. These substates wait for each other to finish to join back into one flow

A nested concurrent state machine does not have an initial, final, or history state



Mix with the vocabulary from activity diagrams

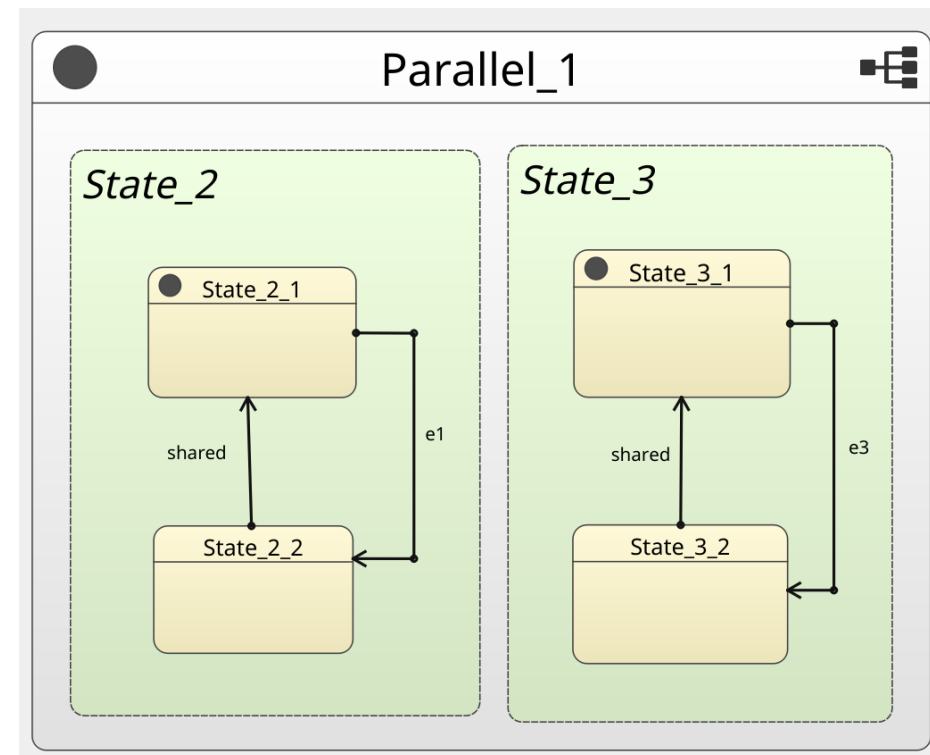
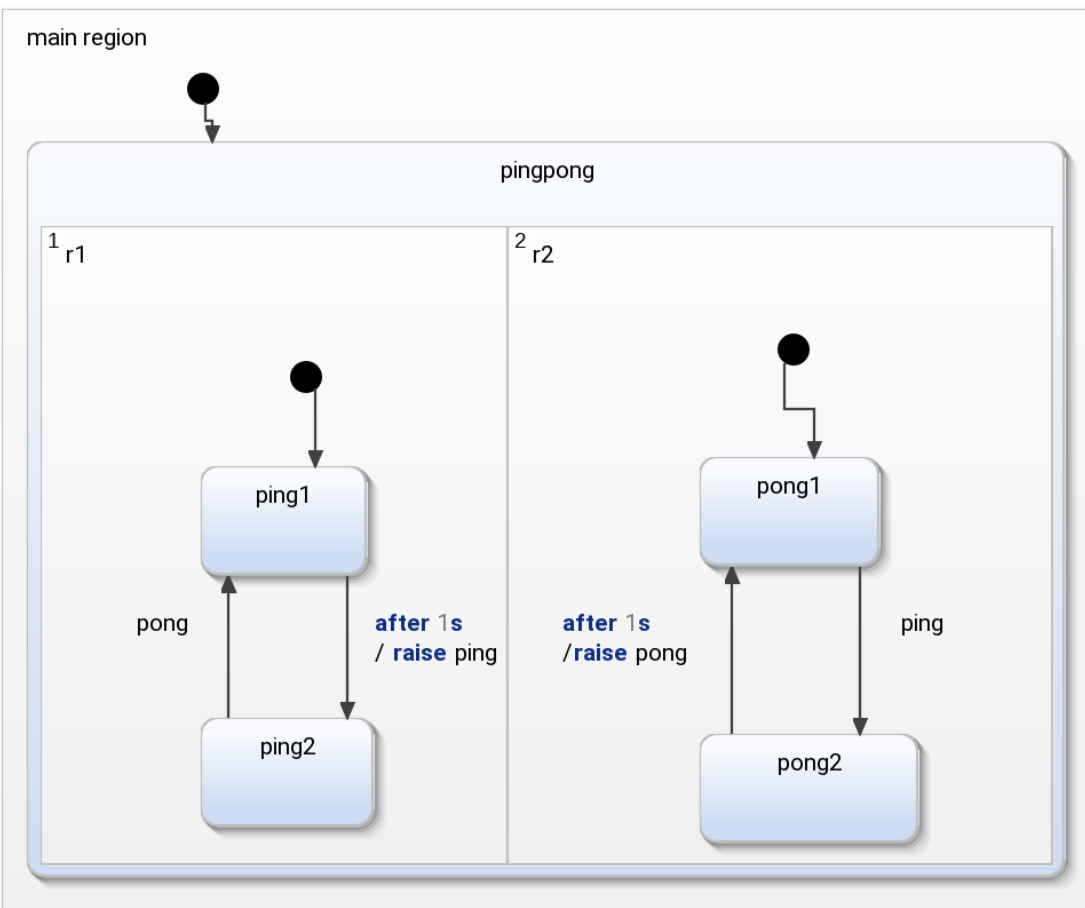
Parallel states

Yet another representation and naming

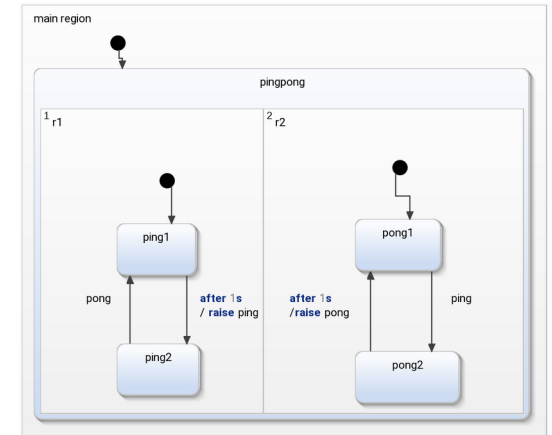
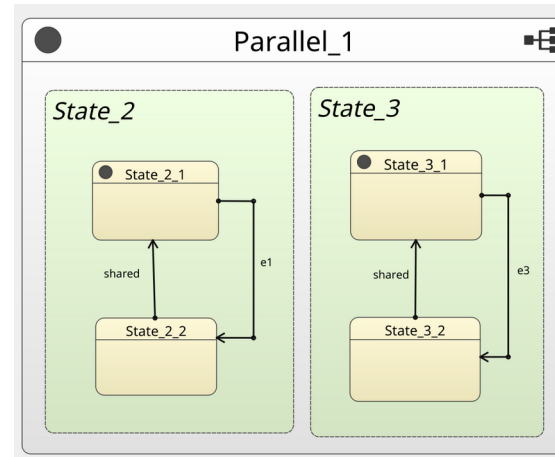
concurrent substates specify two or more state machines that execute in parallel in the context of the enclosing object

Execution of these concurrent substates continues in parallel. These substates wait for each other to finish to join back into one flow

A nested concurrent state machine does not have an initial, final, or history state

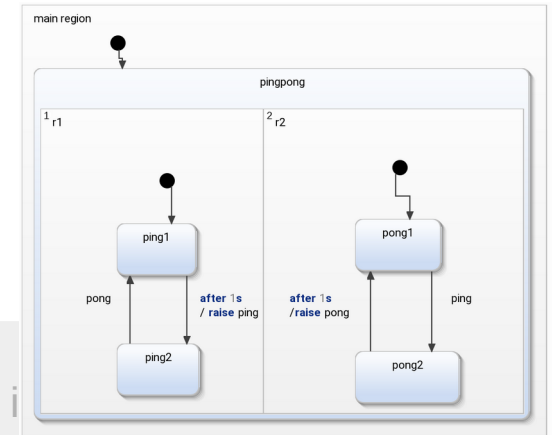
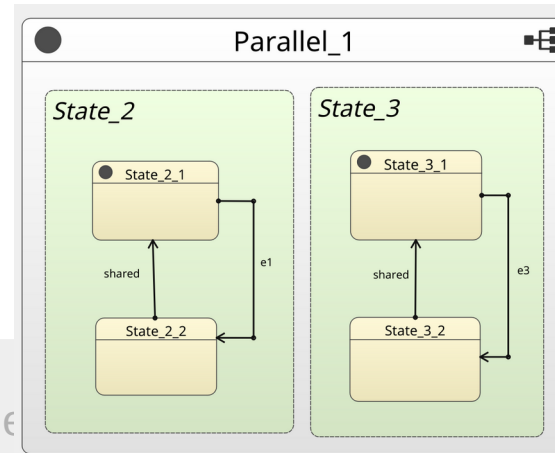


Parallel states



- **Parallel States:**
 - The child states execute in parallel in the sense that any event that is processed is processed in each child state independently, and each child state may take a different transition in response to the event. (Similarly, one child state may take a transition in response to an event, while another child ignores it.) When all of the children reach final states, the `<parallel>` element itself is considered to be in a final state, and a completion event `done.state.id` is generated, where `id` is the id of the `<parallel>` element.
 - Transitions within the individual child elements operate normally. However whenever a transition is taken with a target outside the `<parallel>` element, the `<parallel>` element and all of its child elements are exited and the corresponding `<onexit>` handlers are executed. The handlers for the child elements execute first, in document order, followed by those of the parent `<parallel>` element, followed by an action expression in the `<transition>` element, and then the `<onentry>` handlers in the "target" state.
 - Note that the semantics of the `<parallel>` element does not call for multiple threads or truly concurrent processing. The children of `<parallel>` execute in parallel in the sense that they are all simultaneously active and each one independently selects transitions for any event that is received. However, the parallel children process the event in a defined, serial order, so no conflicts or race conditions can occur. See D Algorithm for SCXML Interpretation for a detailed description of the semantics of `<parallel>` and the rest of SCXML.

Parallel states



- Parallel States:
 - The child states execute in parallel, each child state independently, and each child state may take a different transition in response to the event. (Similarly, one child state may take a transition in response to an event, while another child ignores it.) When all of the children reach final states, the `<parallel>` element itself is considered to be in a final state, and a completion event `done.state.id` is generated, where `id` is

UML:

Even though orthogonal regions imply independence of execution (allowing more or less concurrency), the UML specification does not require that a separate thread of execution be assigned to each orthogonal region (although this can be done if desired). In fact, most commonly, orthogonal regions execute within the same thread*. The UML specification requires only that the designer does not rely on any particular order for event instances to be dispatched to the relevant orthogonal regions.

- Note that the semantics of the `<parallel>` element does not call for multiple threads or truly concurrent processing. The children of `<parallel>` execute in parallel in the sense that they are all simultaneously active and each one independently selects transitions for any event that is received. However, the parallel children process the event in a defined, serial order, so no conflicts or race conditions can occur. See D Algorithm for SCXML Interpretation for a detailed description of the semantics of `<parallel>` and the rest of SCXML.

* Douglass, Bruce Powel (1999). Doing Hard Time: Developing Real-Time Systems with UML, Objects, Frameworks, and Patterns. Addison Wesley. p. 749. ISBN 0-201-49837-5.

SCXML

State Chart XML

Parallel regions, **communications**
and a little bit more

State Charts

statecharts = state-diagrams + depth

+ orthogonality + broadcast-communication.

David Harel

Statecharts: A visual formalism for complex systems

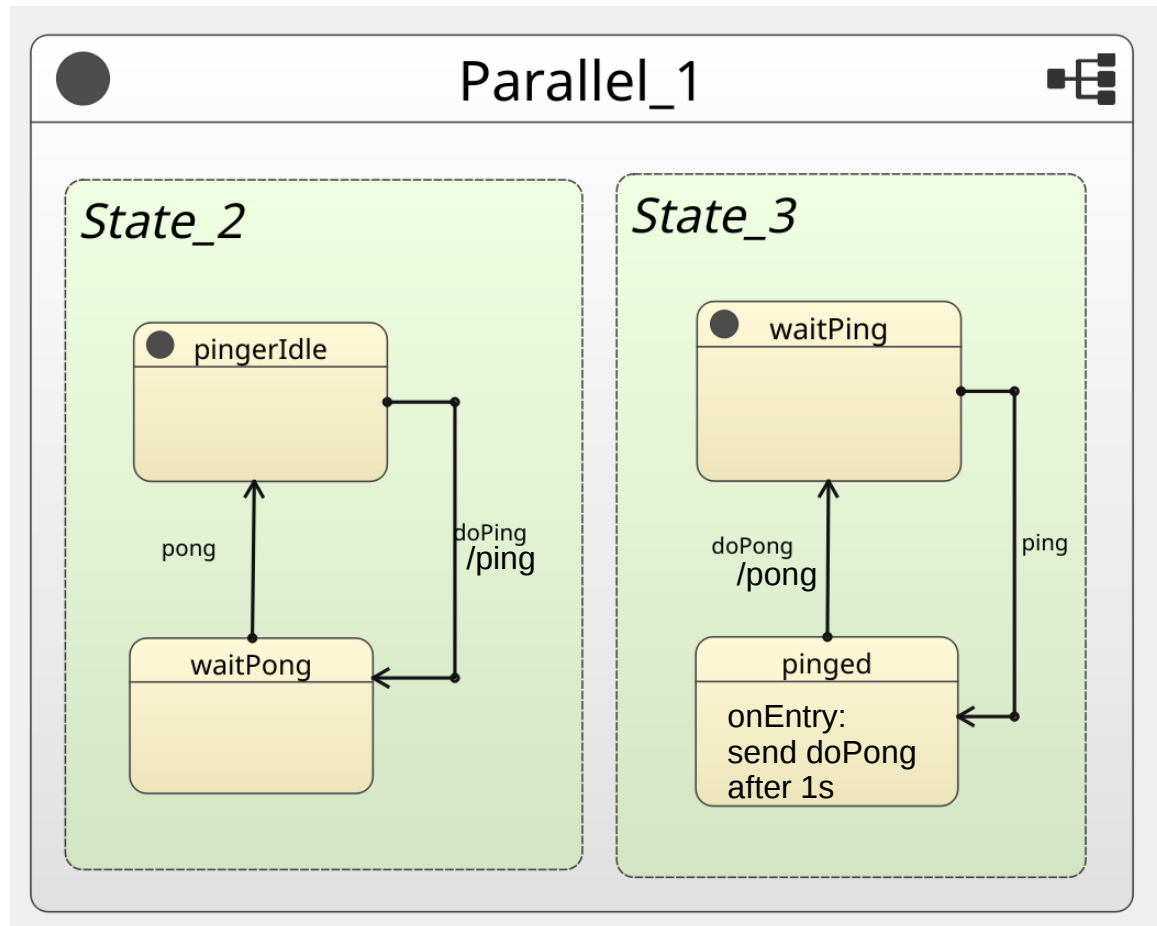
Science of computer programming 8 (3), 231-274

1987

Communication: intuition

Usually, parallel states are not truly independent. The different state machines can communicate through different mechanism (*e.g.*, shared variable or timings) to synchronize their behaviors.

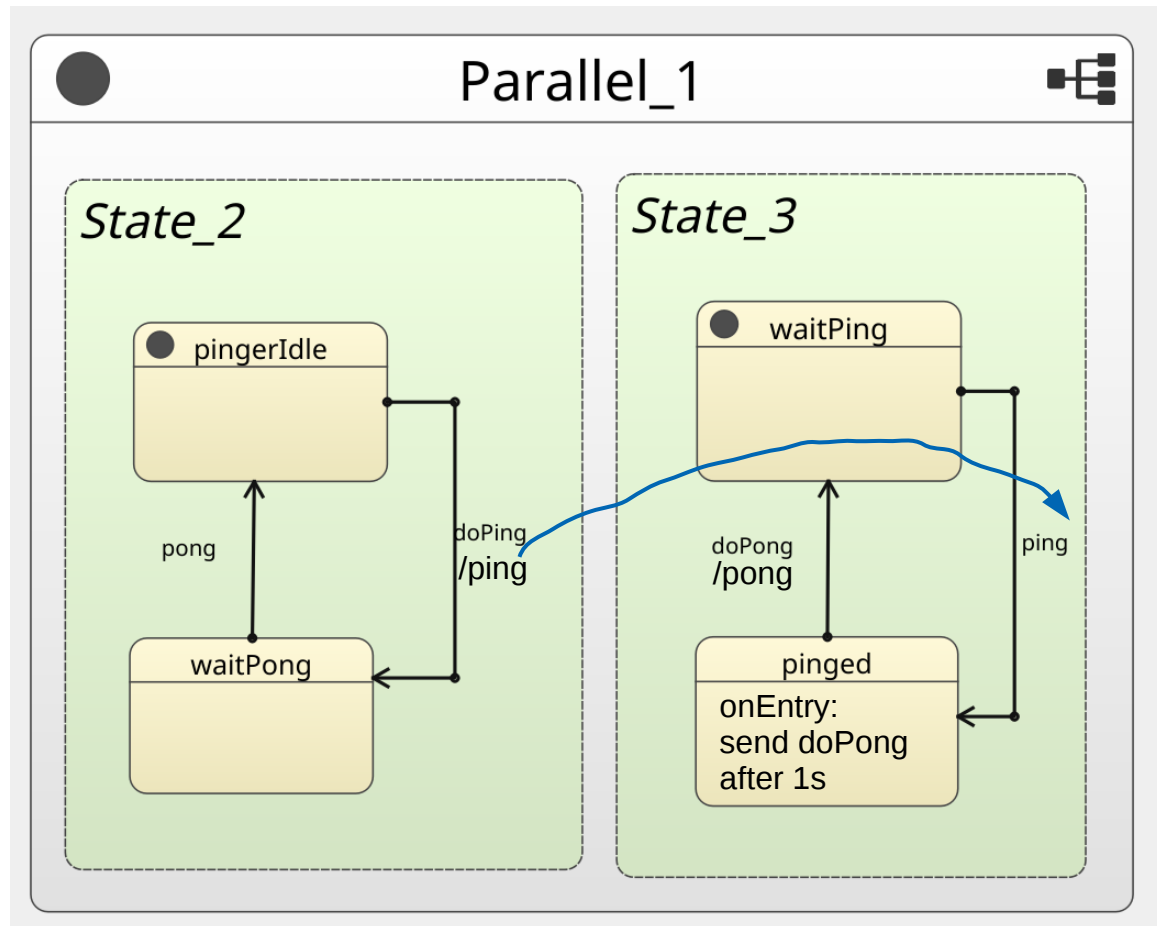
→ The most common way to coordinate behaviors from parallel states is by sending events to each others.



Communication: intuition

Usually, parallel states are not truly independent. The different state machines can communicate through different mechanism (*e.g.*, shared variable or timings) to synchronize their behaviors.

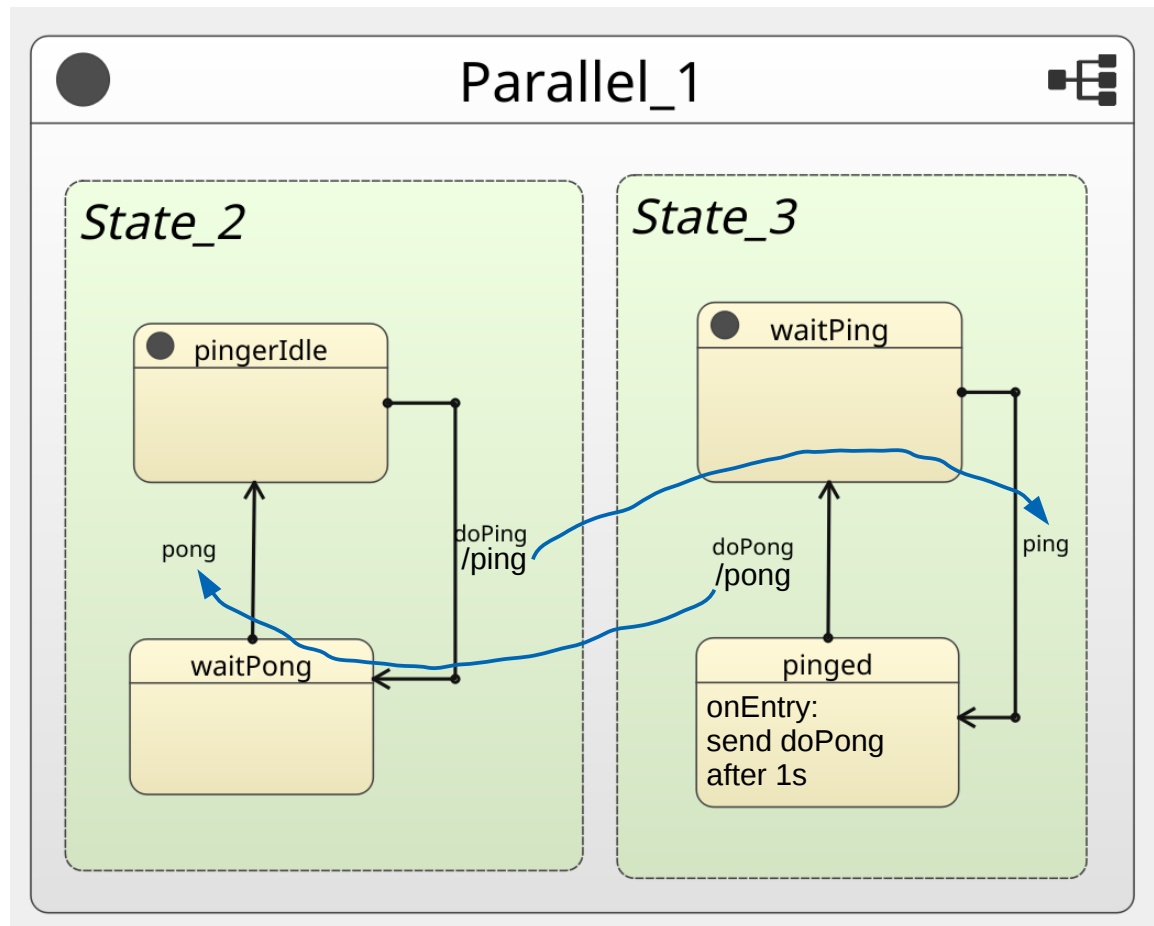
→ The most common way to coordinate behaviors from parallel states is by sending events to each others.



Communication: intuition

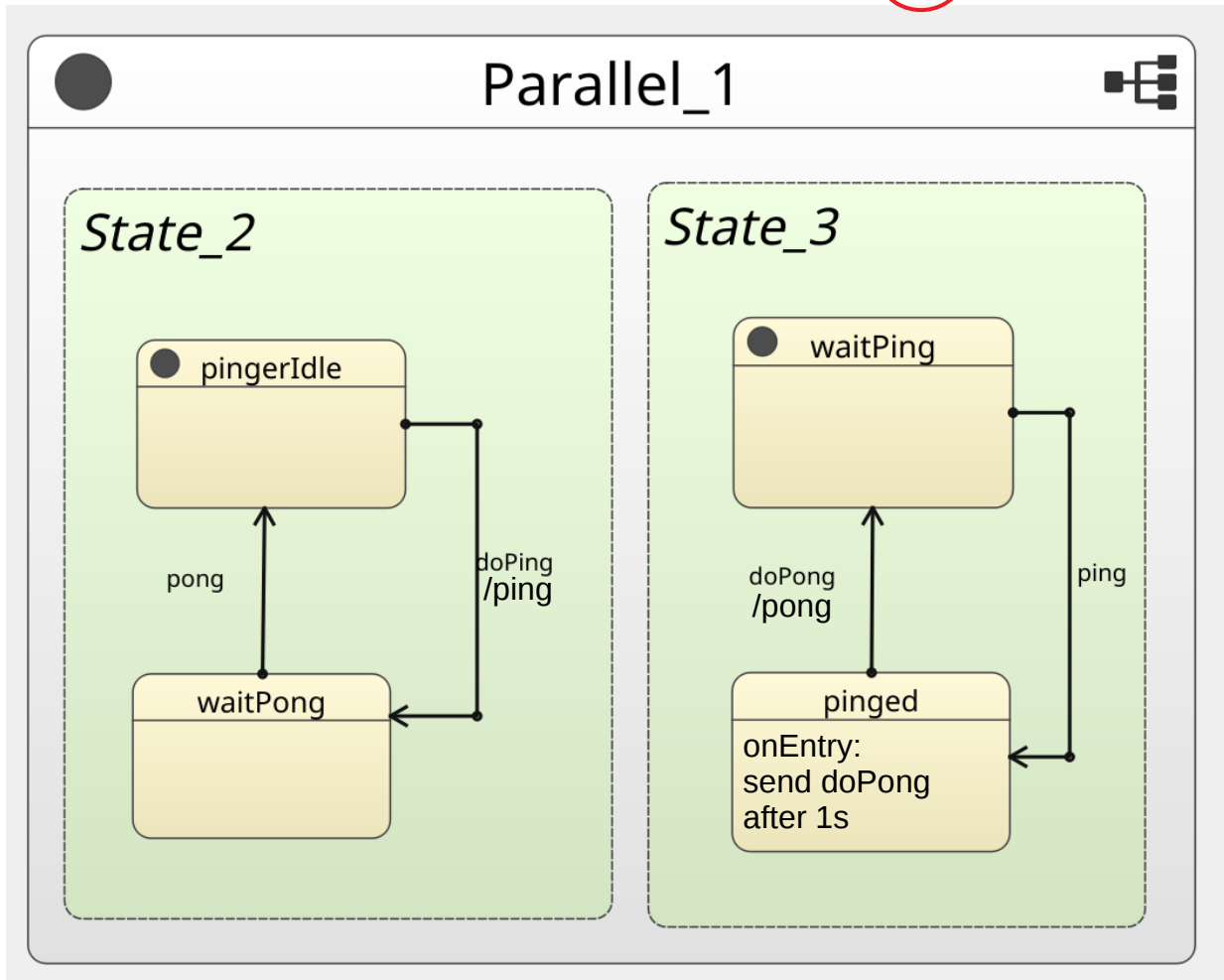
Usually, parallel states are not truly independent. The different state machines can communicate through different mechanism (*e.g.*, shared variable or timings) to synchronize their behaviors.

→ The most common way to coordinate behaviors from parallel states is by sending events to each others.



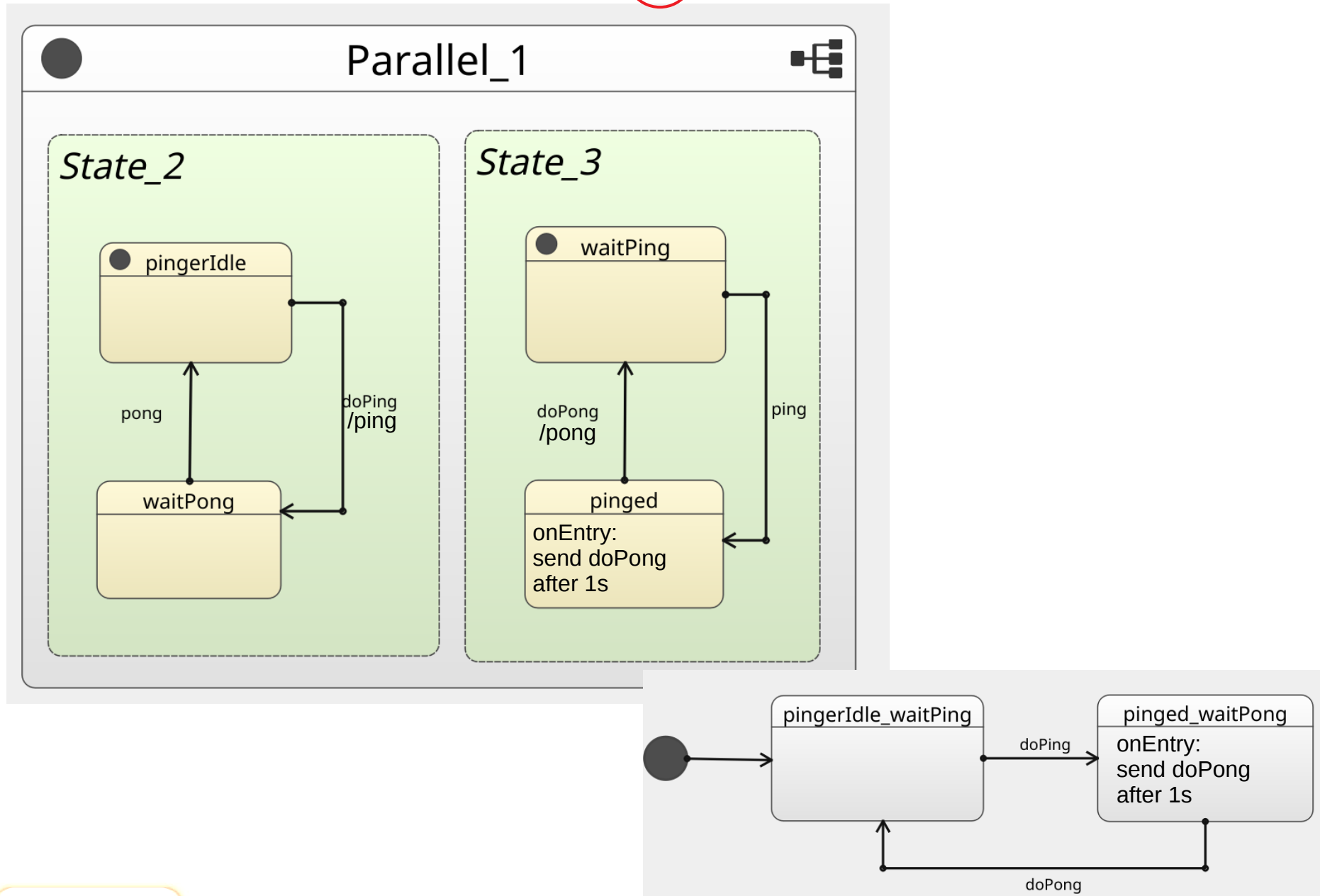
Communication: intuition

The coordination between the parallel states *can* reduce the resulting behavior



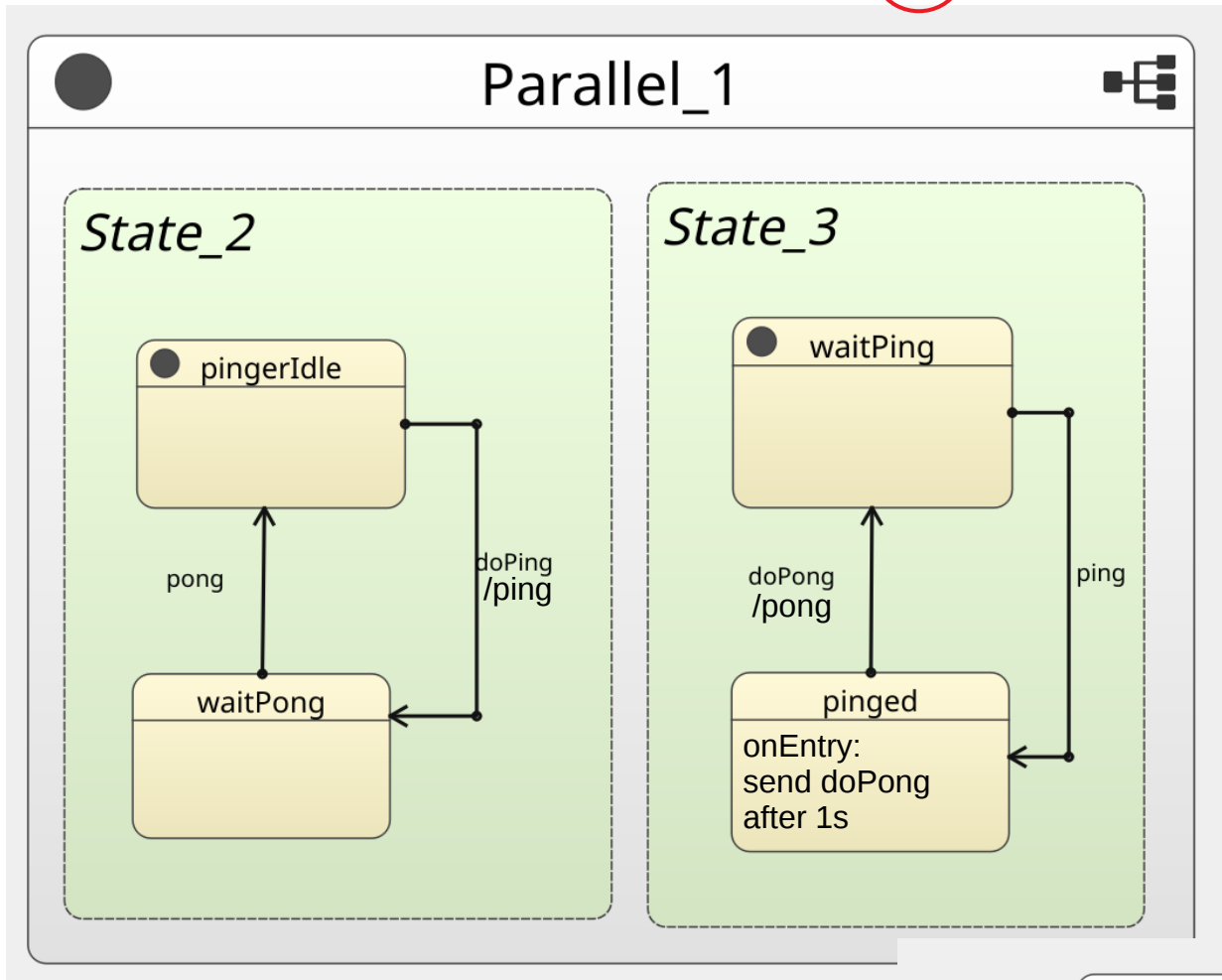
Communication: intuition

The coordination between the parallel states *can* reduce the resulting behavior

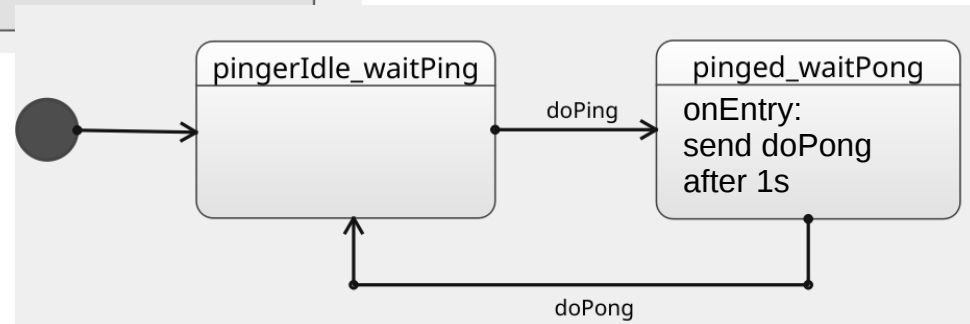


Communication: intuition

The coordination between the parallel states *can* reduce the resulting behavior



If *ping* or *pong* is not sent from the outside !

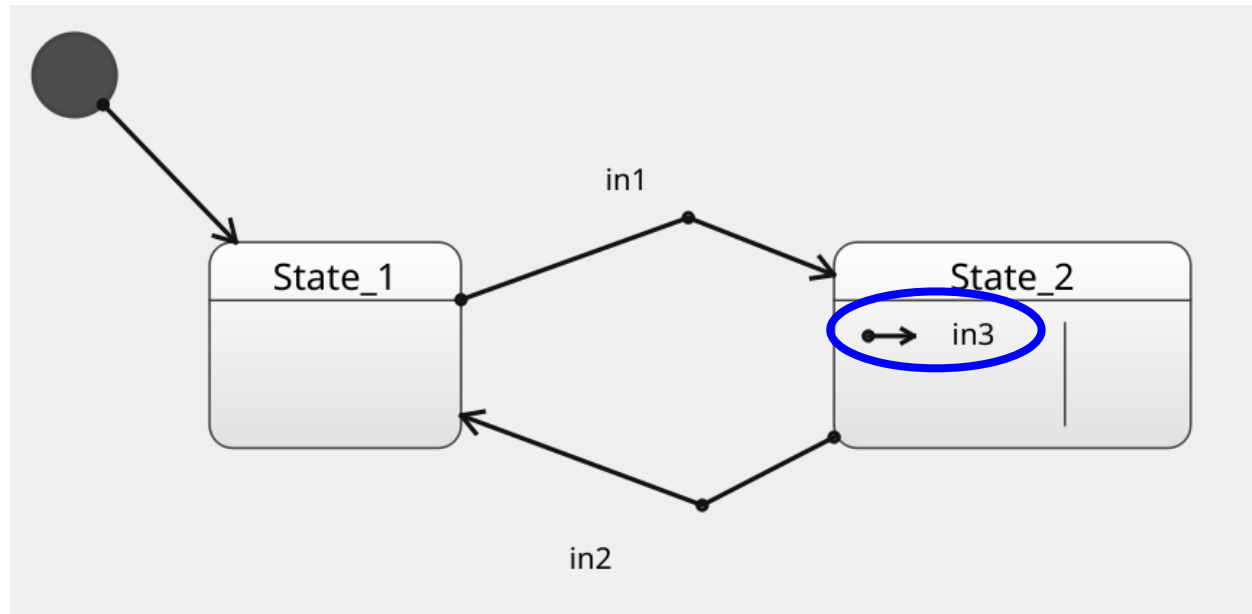


SCXML

State Chart XML

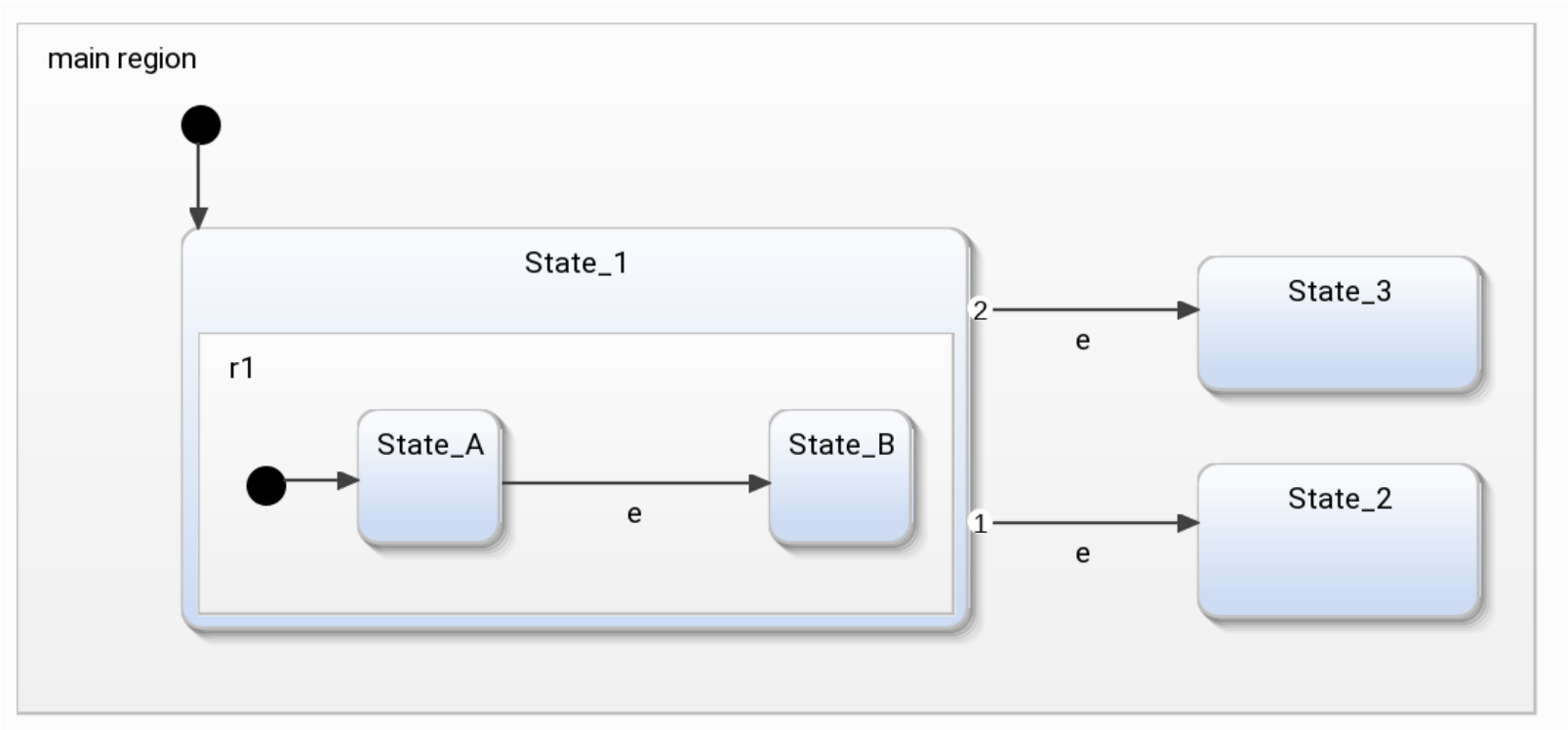
Parallel regions, communications
and **a little bit more**

No target transition



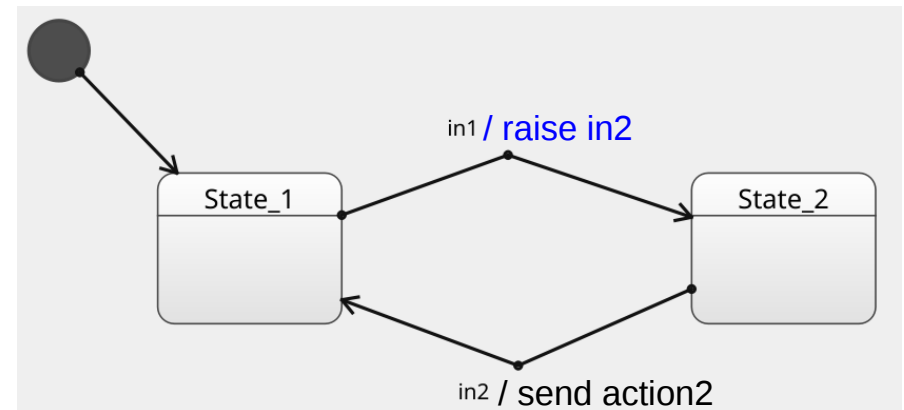
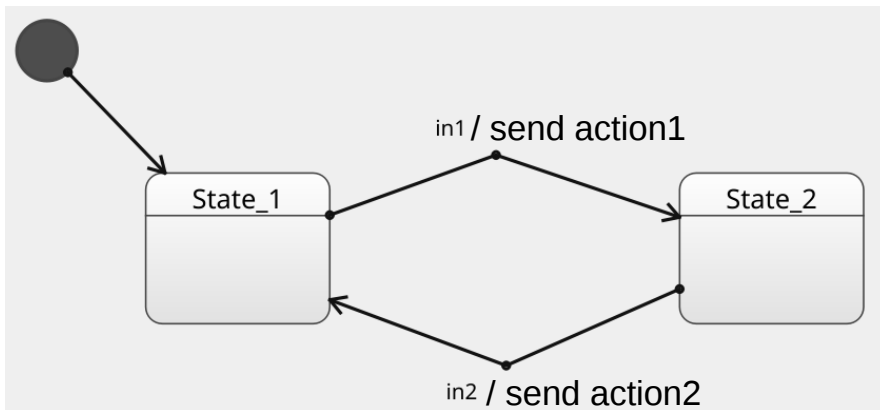
If the 'target' on a <transition> is omitted, then the value of 'type' does not have any effect and taking the transition does not change the state configuration but does invoke the executable content that is included in the transition. Note that this is different from a <transition> whose 'target' is its source state. In the latter case, the state is exited and reentered, triggering execution of its <onentry> and <onexit> executable content

Non Determinism ?



N.B. If two transitions conflict, then taking them both may lead to an illegal configuration. Hence, only one of the transitions may safely be taken. In order to resolve conflicts between transitions, we assign priorities to transitions as follows: let transitions T1 and T2 conflict, where T1 is optimally enabled in atomic state S1, and T2 is optimally enabled in atomic state S2, where S1 and S2 are both active. We say that T1 has a higher priority than T2 if a) T1's source state is a descendant of T2's source state, or b) S1 precedes S2 in document order.

Raise vs send



The `<raise>` element raises an event in the current SCXML session. Note that the event will not be processed until the current block of executable content has completed and all events that are already in the internal event queue have been processed. For example, suppose the `<raise>` element occurs first in the `<onentry>` handler of state *S* followed by executable content elements *ec1* and *ec2*. If event *e1* is already in the internal event queue when *S* is entered, the event generated by `<raise>` will not be processed until *ec1* and *ec2* have finished execution and *e1* has been processed.

`<send>` is used to send events and data to external systems, including external SCXML Interpreters, or to raise events in the current SCXML session.

Datamodel

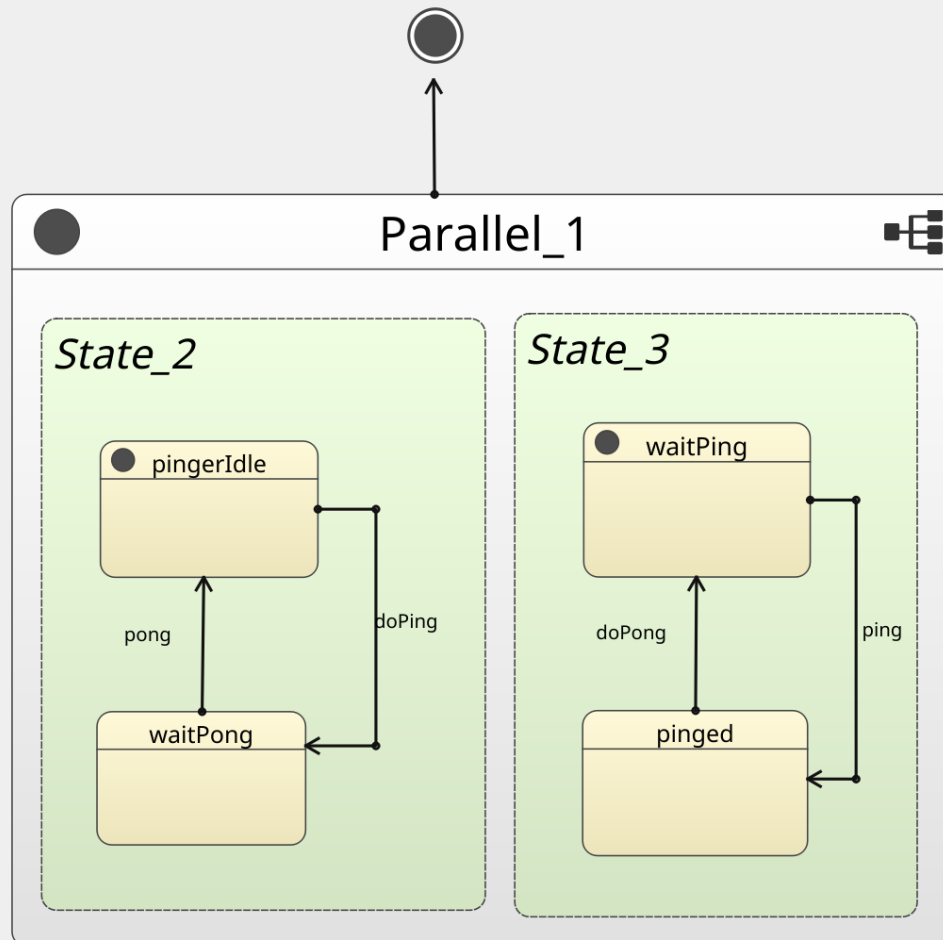
- It is possible to add data and data manipulation directly inside the state machine.
- SCXML supports the ecma script data model (some sort of C++ in Qt Creator and a specific action language in Yakindu)
- *Usually*^{*}, only data directly associated with the control is used in the state machine
 - To avoid mixing the application logic between the code and the state chart
 - To ease the V&V activities

** it strongly depends on what the state chart is used for but it seems to be a good practice, even for understanding*

Datamodel



When ecmaScript data model is used,
the log expr must not be null and it
must conform the ecmaScript syntax
→ otherwise no log is printed



Structure

- scxml
 - datamodel
 - data
 - data
 - Parallel_1
 - onentry
 - State_2
 - pingerIdle
 - doPing
 - assign
 - send
 - log
 - waitPong
 - pong
 - State_3
 - waitPing
 - ping
 - pinged
 - doPong
 - send
 - log
 - onentry
 - send

transition

Attributes

Name	Value
initial	
name	TestPingPong
*xmlns	http://www.w3.org/2005/07/scxml
*version	1.0
datamodel	ecmaScript
binding	early

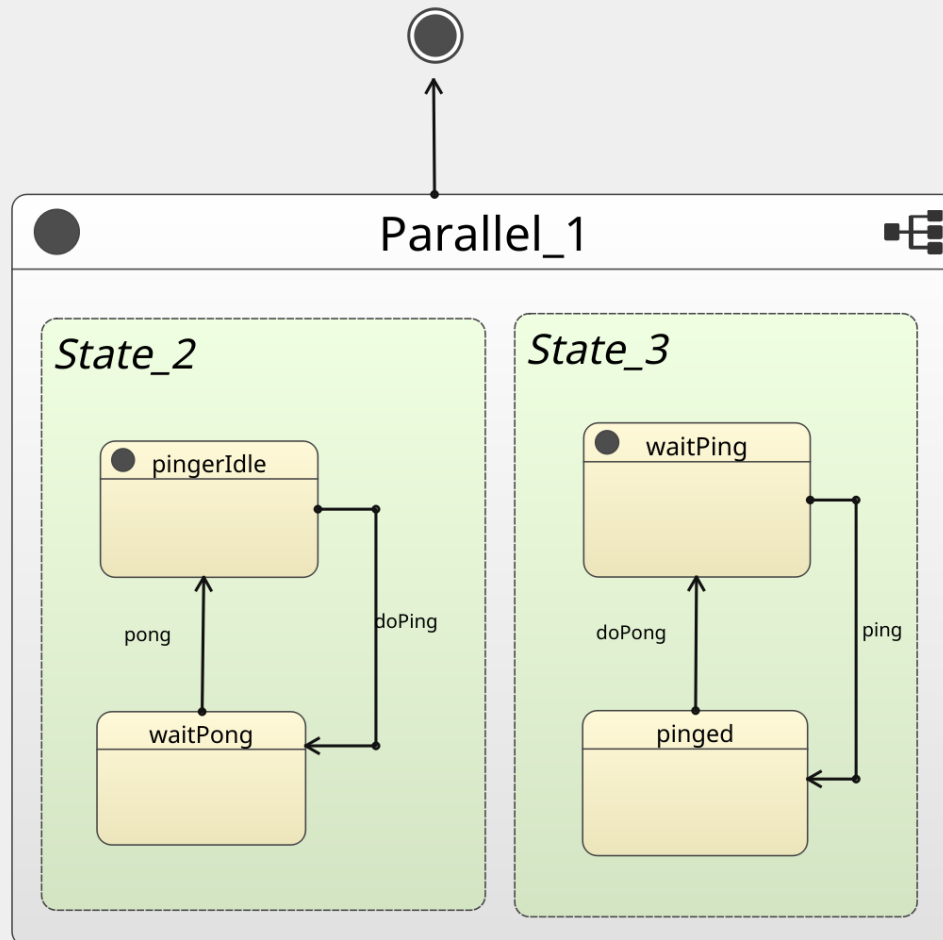
Datamodel

Variables are declared and initialized in a specific section

id: The name of the data item. See 3.14 IDs for details.

src: Gives the location from which the data object should be fetched. See 5.9.3 Legal Data Values and Value Expressions for details.

expr: Evaluates to provide the value of the data item. See 5.9.3 Legal Data Values and Value Expressions for details.



Structure

- scxml
 - datamodel
 - data
 - Parallel_1
 - onentry
 - State_2
 - pingerIdle
 - doPing
 - assign
 - send
 - log
 - waitPong
 - pong
 - State_3
 - waitPing
 - ping
 - pinged
 - doPong
 - send
 - log
 - onentry
 - send
 - transition

Attributes

Name	Value
*id	counter
src	
expr	0

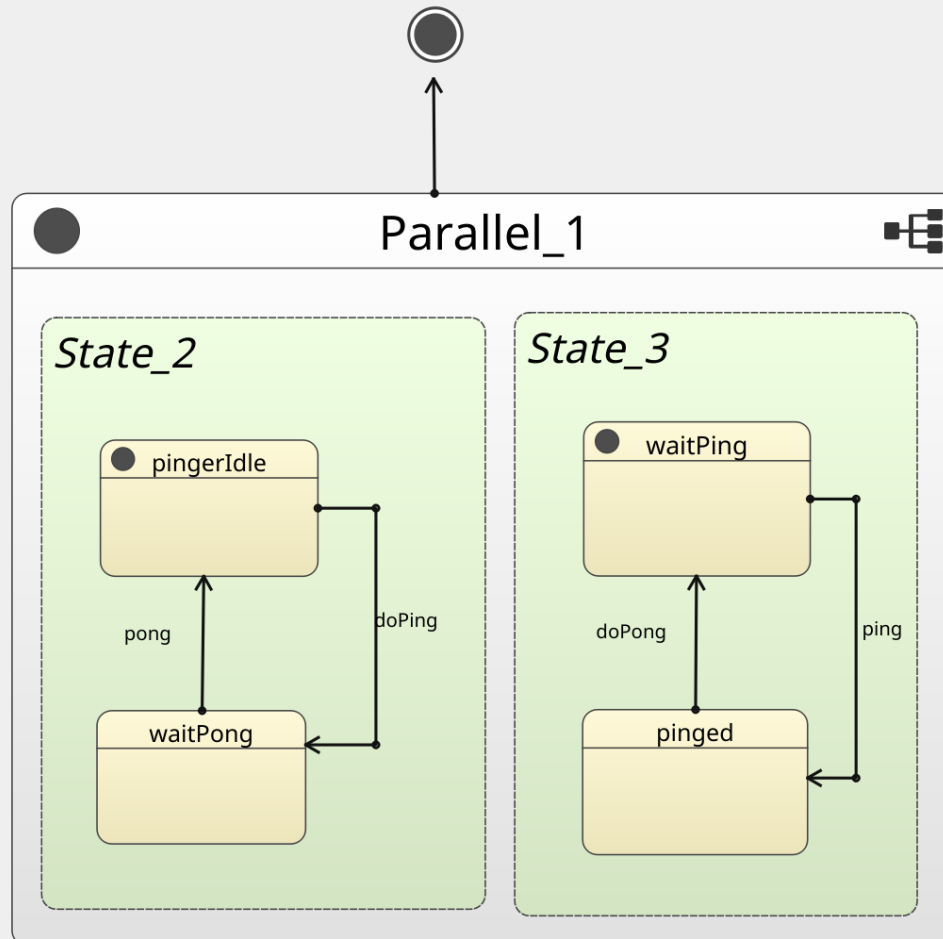
Datamodel

Variables are declared and initialized in a specific section

id: The name of the data item. See 3.14 IDs for details.

src: Gives the location from which the data object should be fetched. See 5.9.3 Legal Data Values and Value Expressions for details.

expr: Evaluates to provide the value of the data item. See 5.9.3 Legal Data Values and Value Expressions for details.



Structure

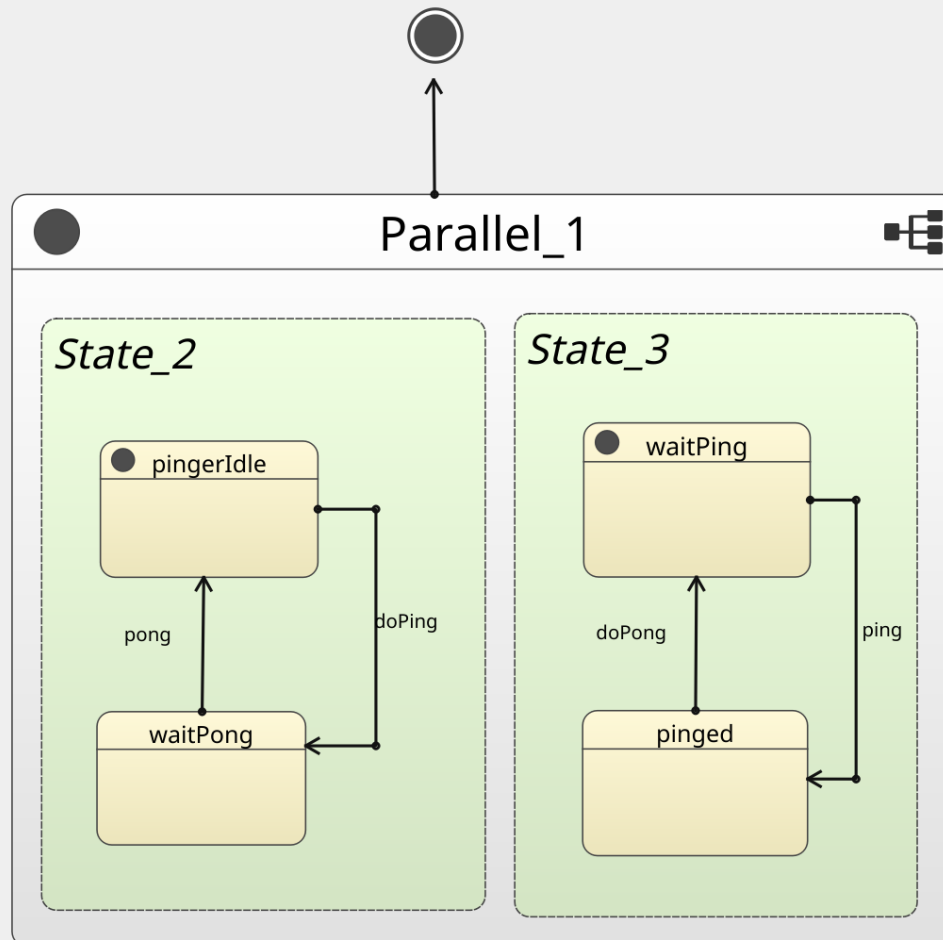
- scxml
 - datamodel
 - data
 - data
 - Parallel_1
 - onentry
 - State_2
 - pingerIdle
 - doPing
 - assign
 - send
 - log
 - waitPong
 - pong
 - State_3
 - waitPing
 - ping
 - pinged
 - doPong
 - send
 - log
 - onentry
 - send
 - transition

Attributes

Name	Value
*id	startTime
src	
expr	new Date().getTime()

Datamodel

Label is any string and expr any legal ecma script expression
(if no expression, needs to be ' ')



Structure

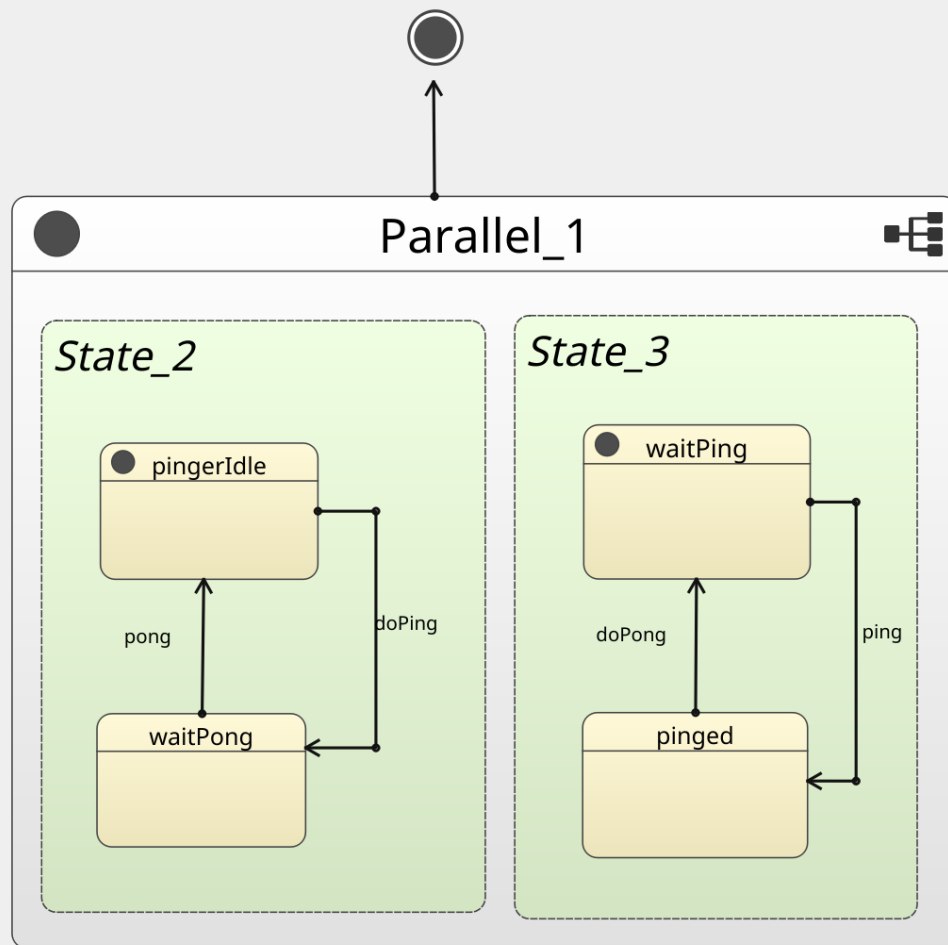
- scxml
 - datamodel
 - data
 - data
 - Parallel_1
 - onentry
 - State_2
 - pingerIdle
 - doPing
 - assign
 - send
 - log
 - waitPong
 - pong
 - State_3
 - waitPing
 - ping
 - pinged
 - doPong
 - send
 - log
 - onentry
 - send

transition

Attributes

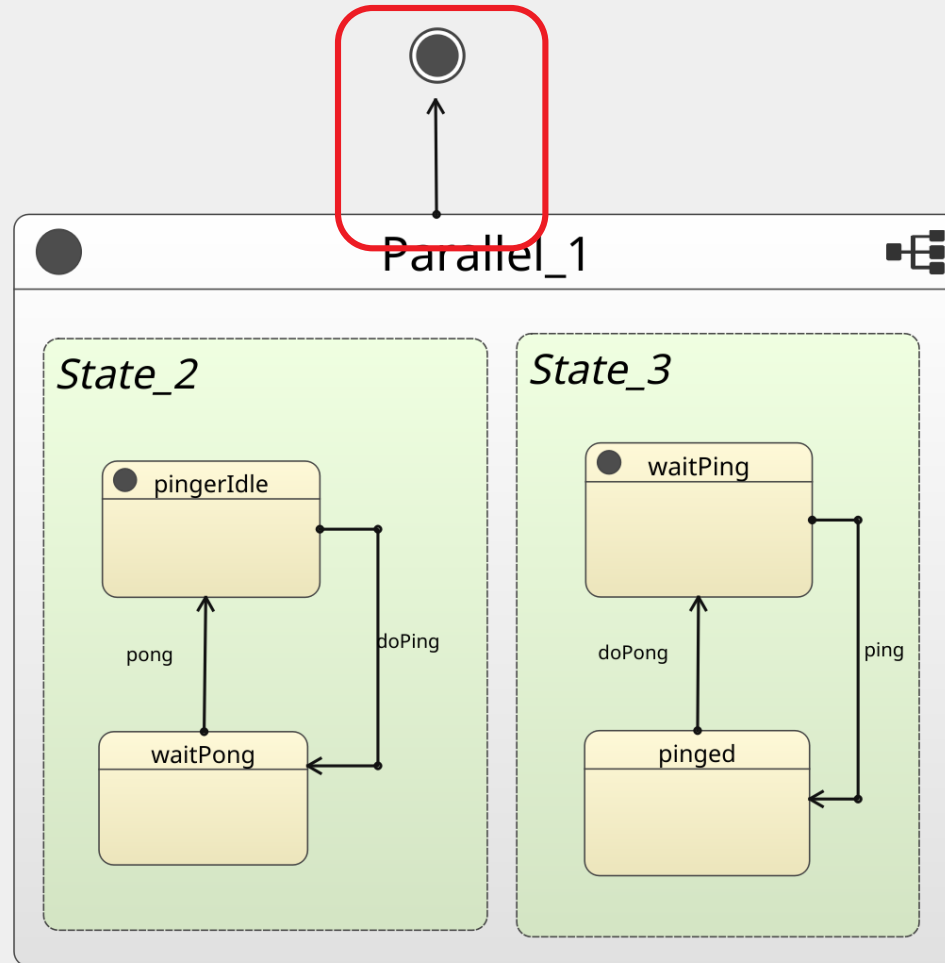
Name	Value
label	ping
expr	new Date().getTime() - startTime +"ms"

Datamodel



Structure	
scxml	
datamodel	
data	
data	
Parallel_1	
onentry	
State_2	
pingerIdle	
doPing	
assign	
send	
log	
waitPong	
pong	
State_3	
waitPing	
ping	
pinged	
doPong	
send	
log	
onentry	
send	
transition	
Attributes	
Name	Value
event	
cond	counter > 3
target	Final_1
type	external

Datamodel



Structure

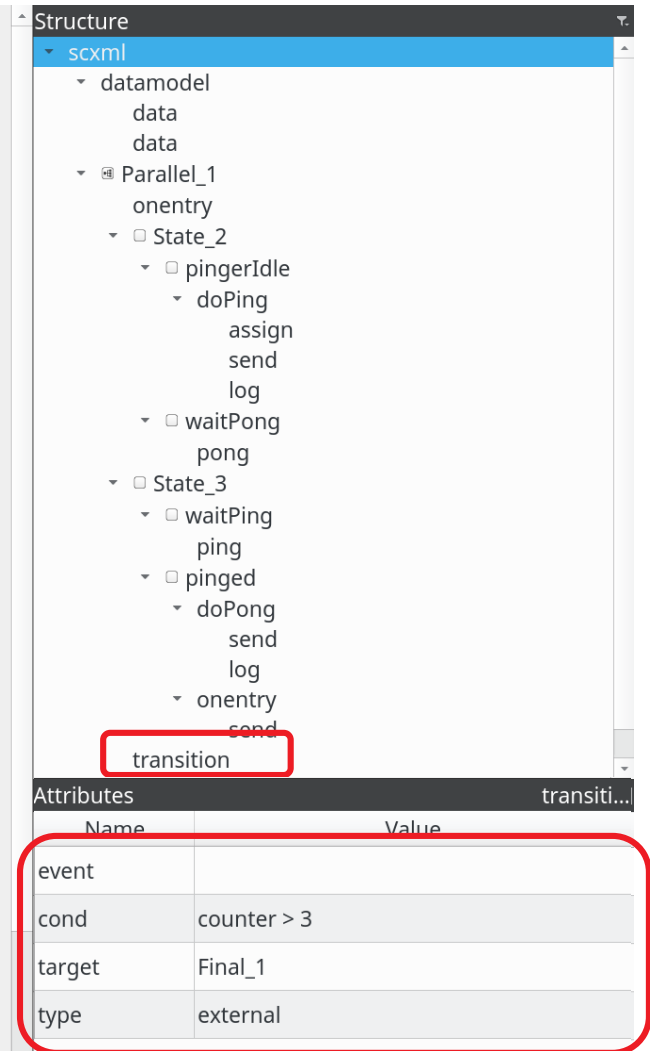
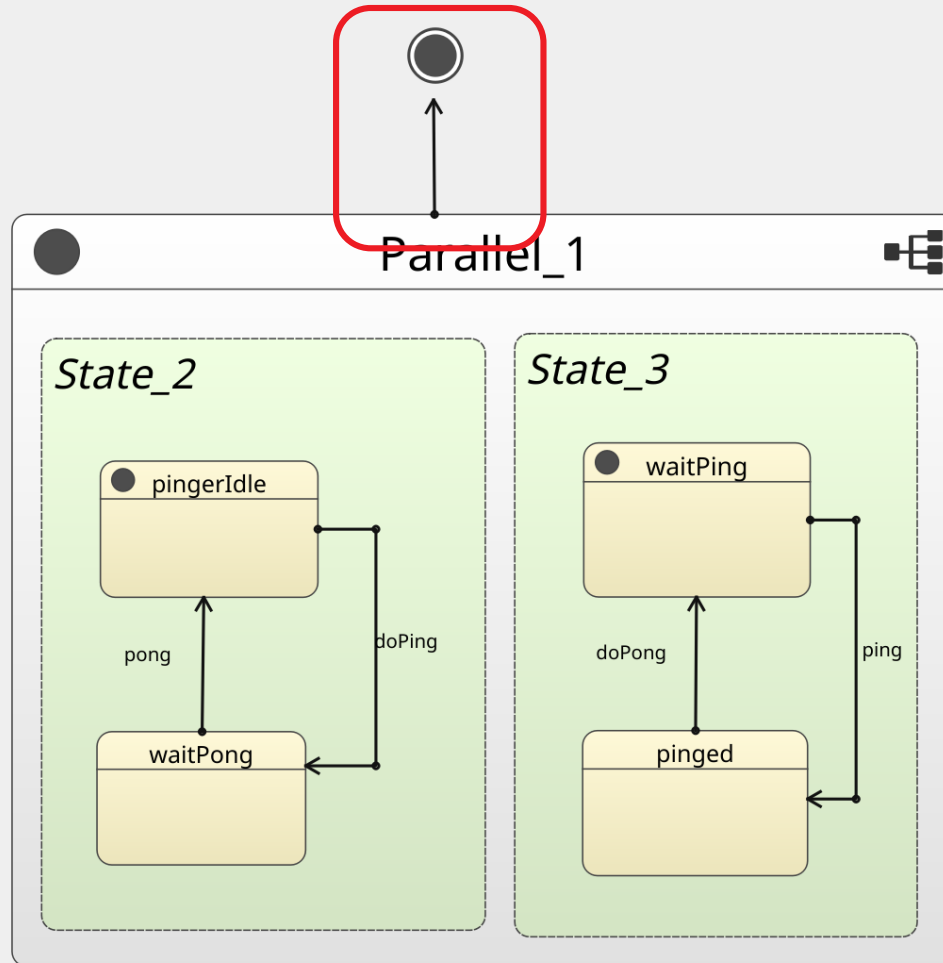
- scxml
 - datamodel
 - data
 - data
 - Parallel_1
 - onentry
 - State_2
 - pingerIdle
 - doPing
 - assign
 - send
 - log
 - waitPong
 - pong
 - State_3
 - waitPing
 - ping
 - pinged
 - doPong
 - send
 - log
 - onentry
 - cond

transition

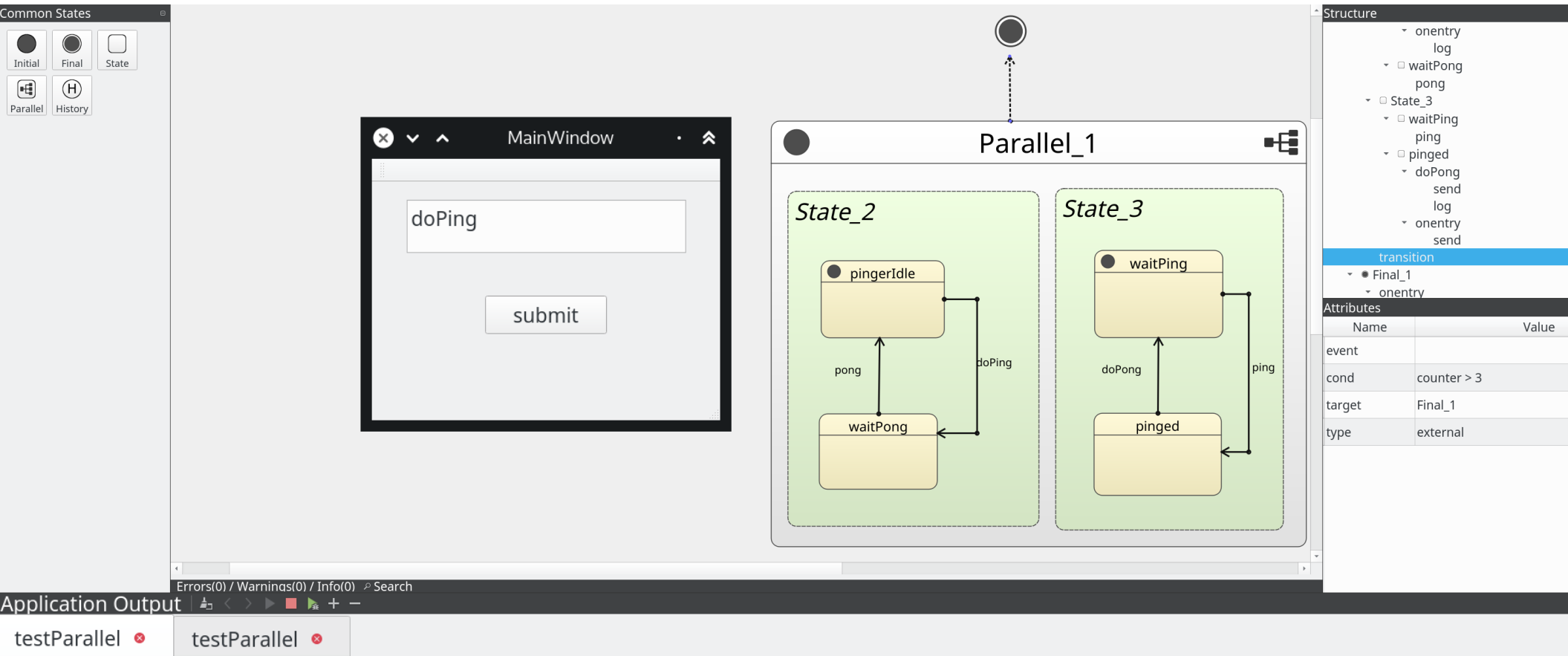
Name	Value
event	
cond	counter > 3
target	Final_1
type	external

Guarded transition

cond: is evaluated after each micro step and fired when the condition holds

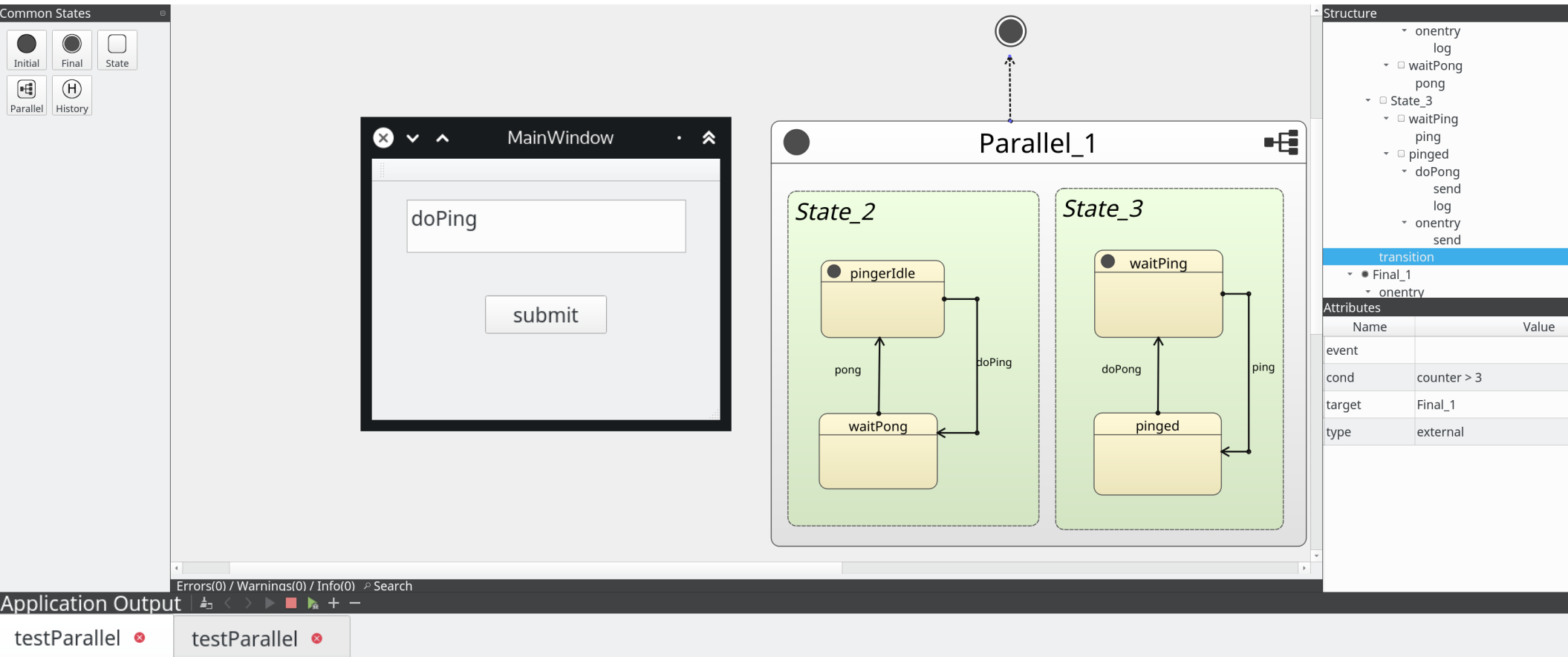


Guarded transition



```
scxml.statemachine: "enter pingerIdle" : "counter = 0"
scxml.statemachine: "ping" : "35199ms"
scxml.statemachine: "pong" : "36251ms"
scxml.statemachine: "enter pingerIdle" : "counter = 1"
scxml.statemachine: "ping" : "37800ms"
scxml.statemachine: "pong" : "38753ms"
scxml.statemachine: "enter pingerIdle" : "counter = 2"
scxml.statemachine: "ping" : "39531ms"
scxml.statemachine: "pong" : "40584ms"
scxml.statemachine: "enter pingerIdle" : "counter = 3"
scxml.statemachine: "ping" : "42640ms"
scxml.statemachine: "enter final node" : "counter =4"
```

Guarded transition



```
scxml.statemachine: "enter pingerIdle" : "counter = 0"
scxml.statemachine: "ping" : "35199ms"
scxml.statemachine: "pong" : "36251ms"
scxml.statemachine: "enter pingerIdle" : "counter = 1"
scxml.statemachine: "ping" : "37800ms"
scxml.statemachine: "pong" : "38753ms"
scxml.statemachine: "enter pingerIdle" : "counter = 2"
scxml.statemachine: "ping" : "39531ms"
scxml.statemachine: "pong" : "40584ms"
scxml.statemachine: "enter pingerIdle" : "counter = 3"
scxml.statemachine: "ping" : "42640ms"
scxml.statemachine: "enter final node" : "counter =4"
```

QtCreator and SCXML more generally consider the time to be the physical “wall clock” time. It is obviously not the case for all timed (and critical) systems for which symbolic reasoning is done

