Modeling and Specification of QLOCK in OTS/CafeOBJ

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Topics

- What is QLOCK?
- Modeling and Description of QLOCK in OTS
- Formal specification of QLOCK in OTS/CafeOBJ
- Formal specification of mutual exclusion property of QLOCK

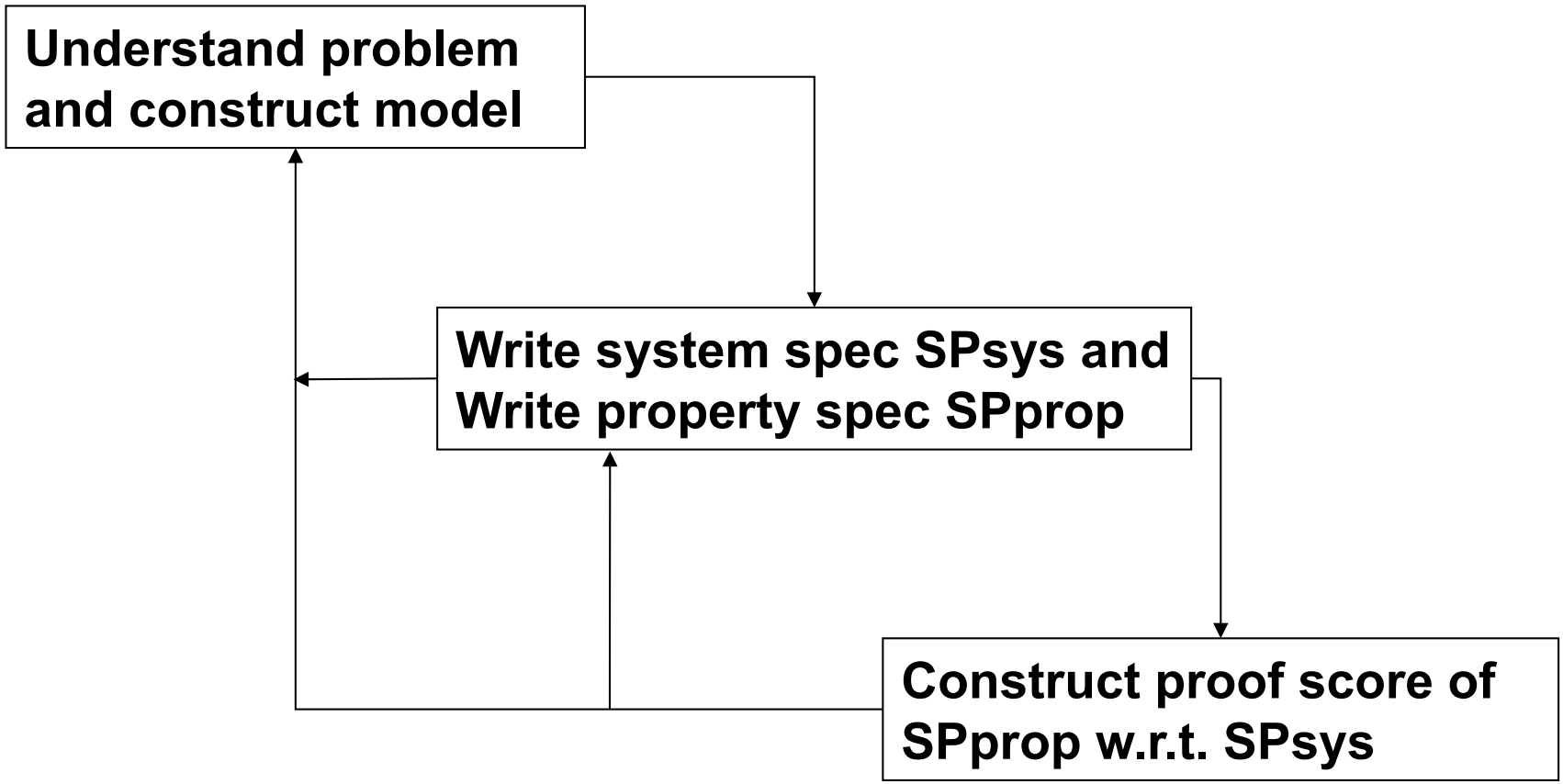
Modeling, Specifying, and Verifying (MSV) in CafeOBJ

1. By understanding a problem to be modeled/ specified, determine several sorts of objects (entities, data, agents, states) and operations (functions, actions, events) over them for describing the problem

2. Define the meanings/functions of the operations by declaring equations over expressions/terms composed of the operations

3. Write proof scores for properties to be verified

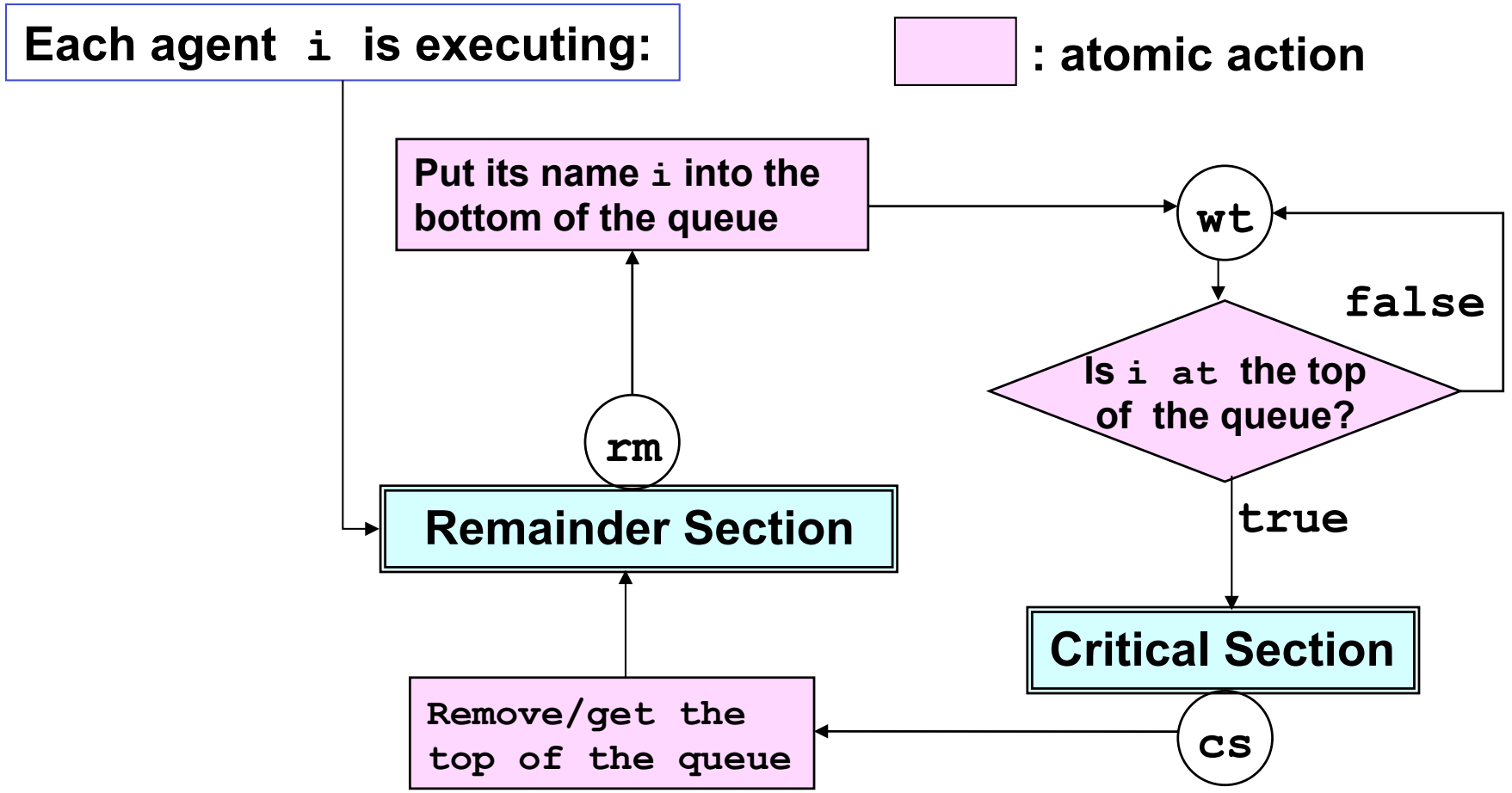
MSV with proof scores in CafeOBJ



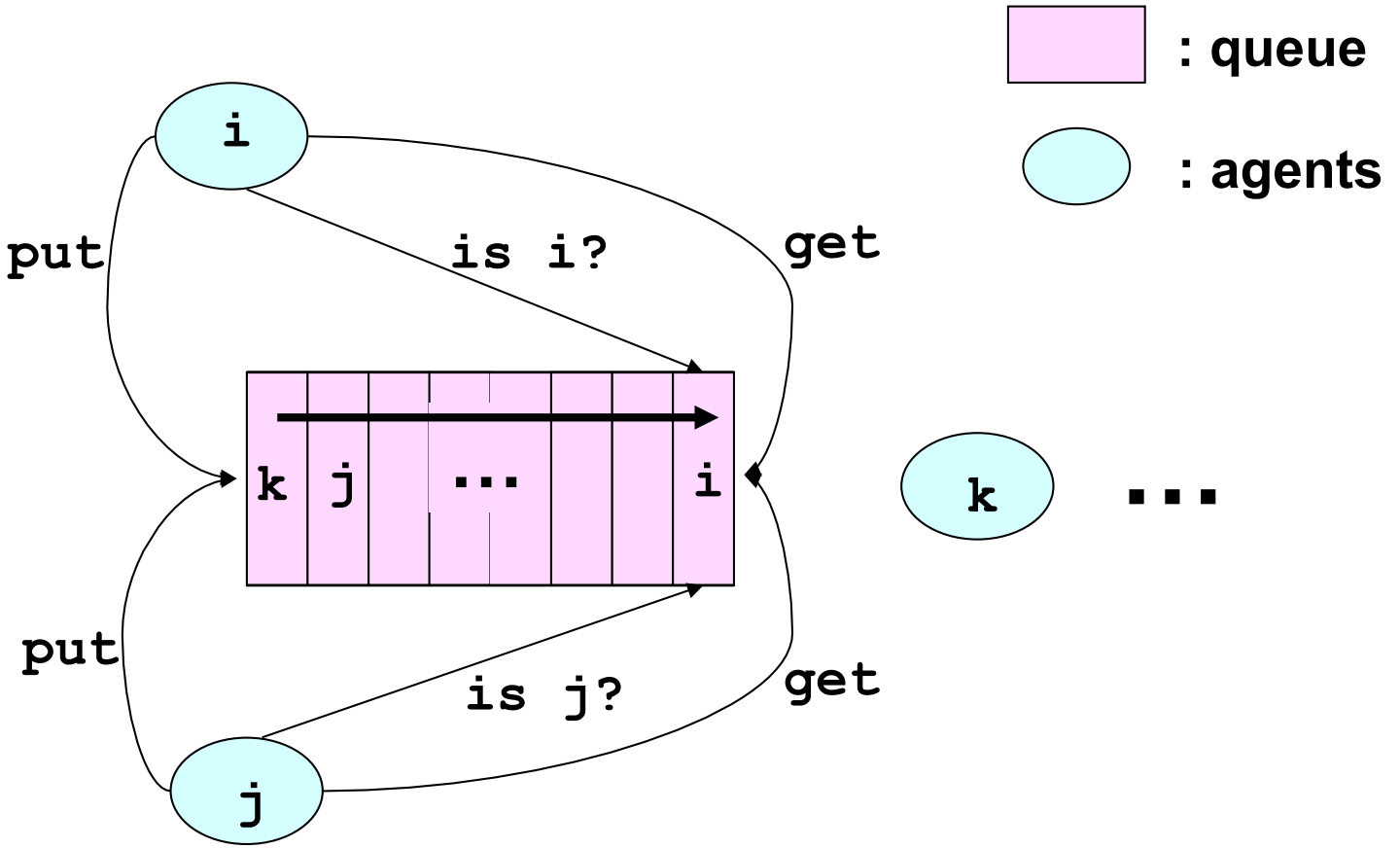
An example: mutual exclusion protocol

Assume that many agents (or processes) are competing for a common equipment, but at any moment of time only one agent can use the equipment. That is, the agents are mutually excluded in using the equipment. A protocol (mechanism or algorithm) which can achieve the mutual exclusion is called "mutual exclusion protocol".

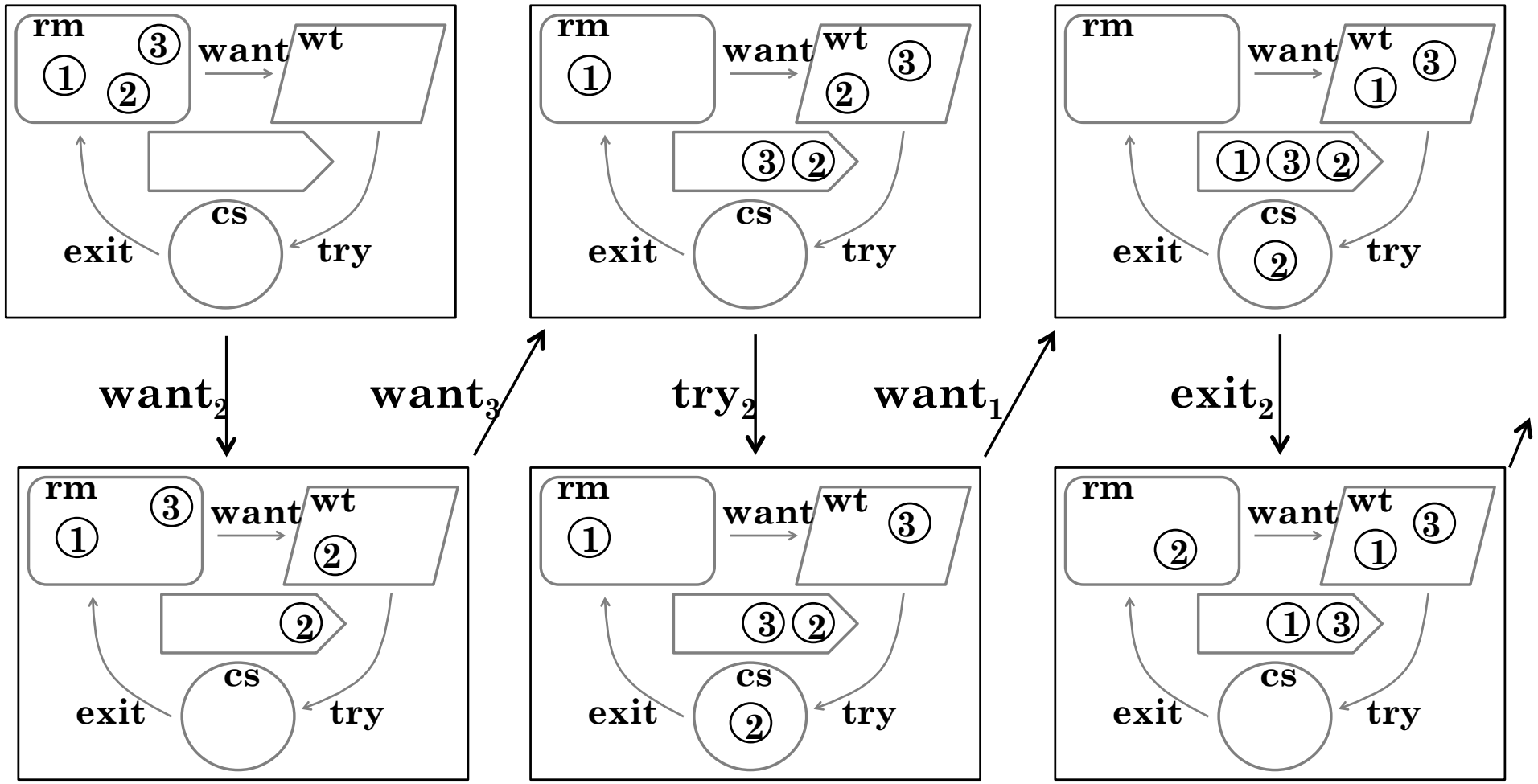
QLOCK (locking with queue): a mutual exclusion protocol



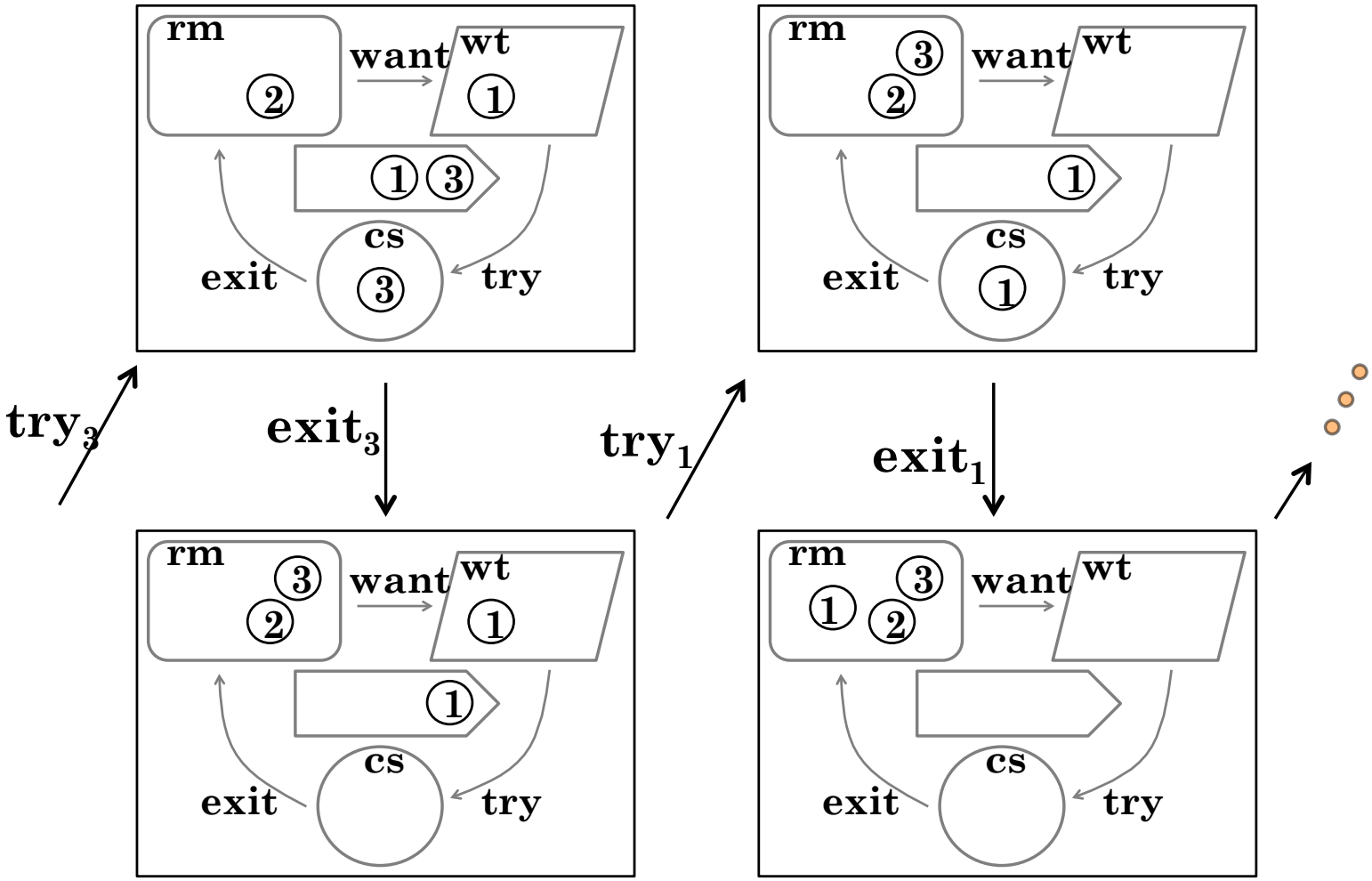
Global (or macro) view of QLOCK



Some Scenario of Qlock (1)



Some Scenario of Qlock (2)

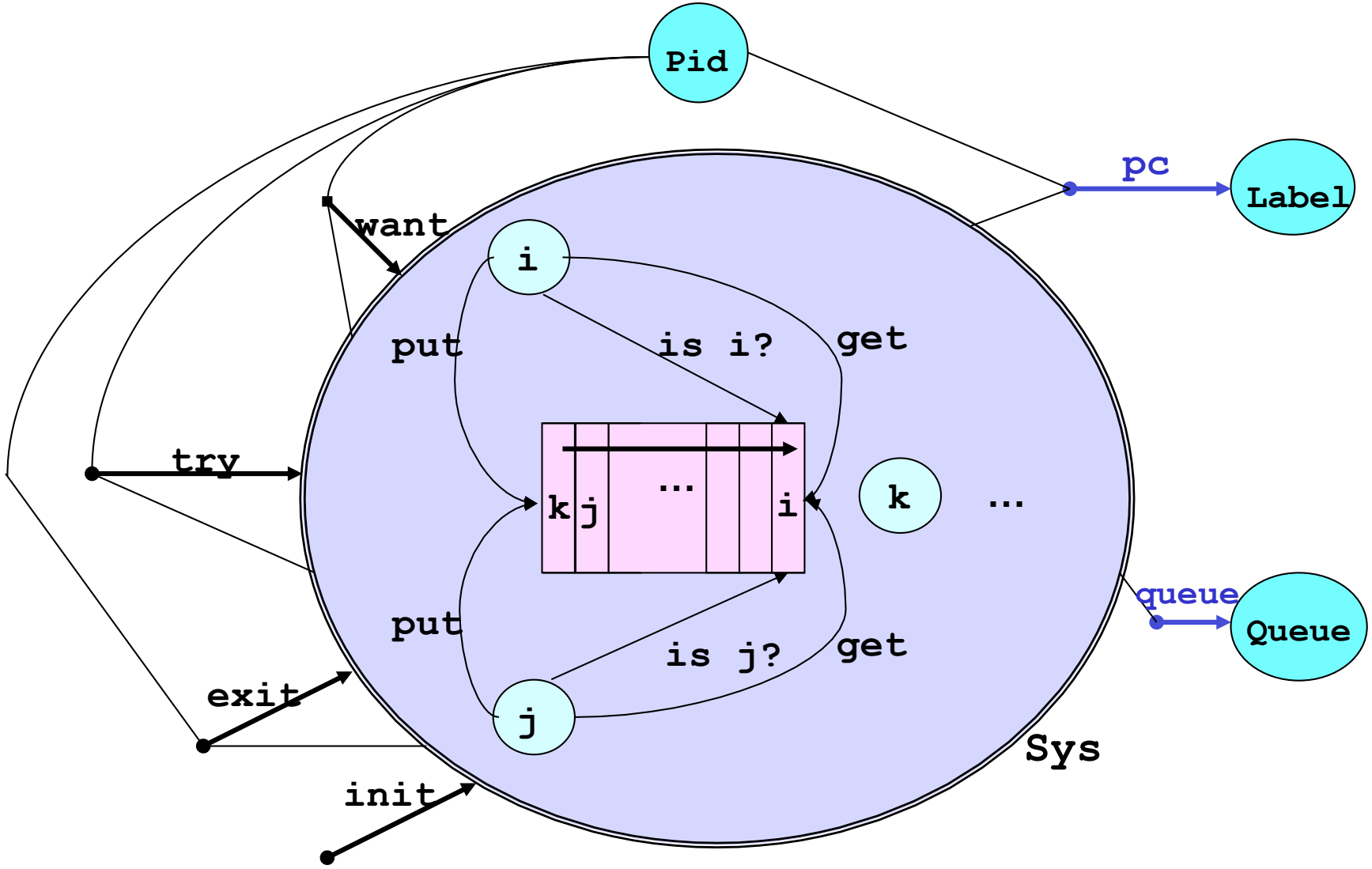


QLOCK: basic assumptions/characteristics

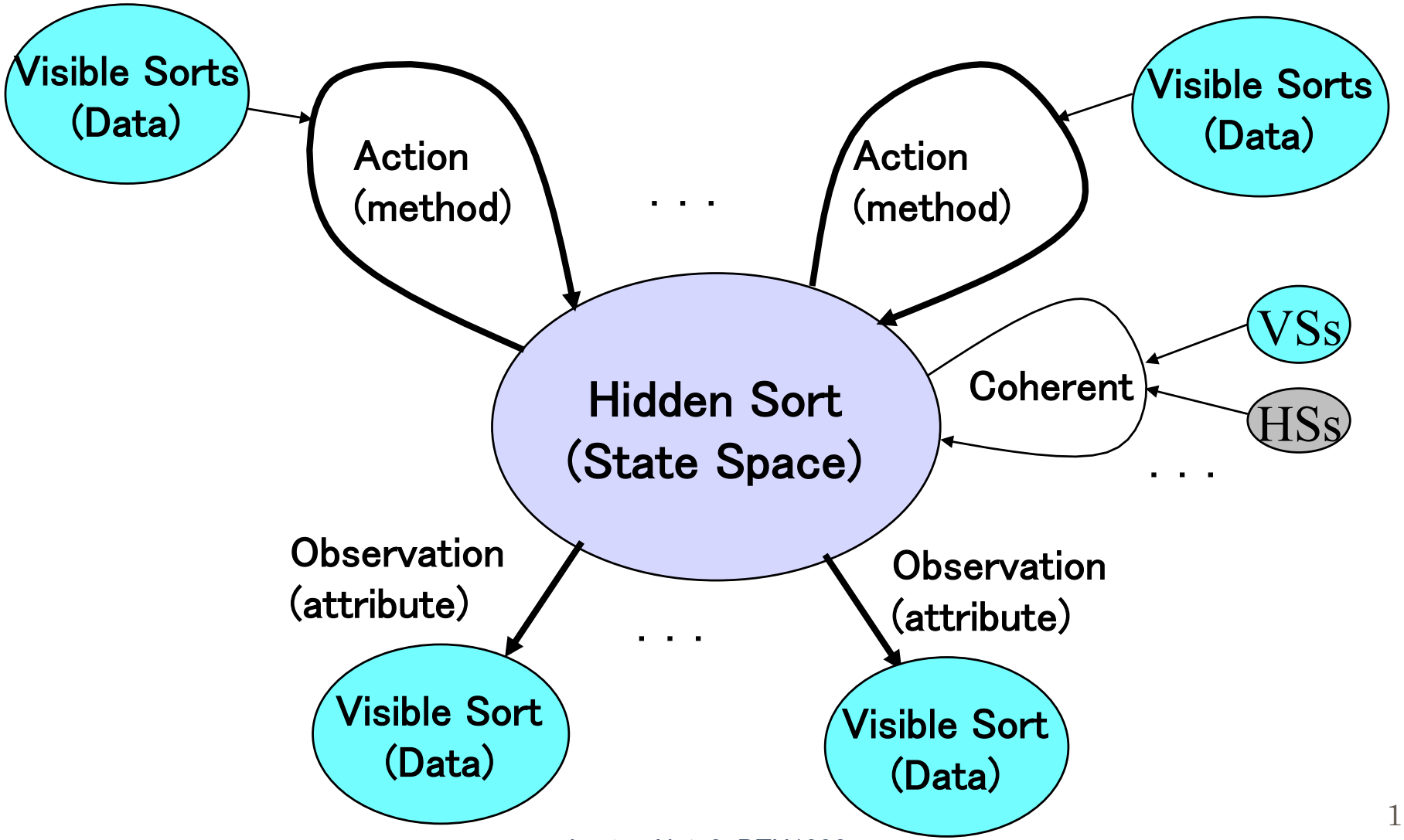
- There is only one queue and all agents/processes share the queue.
- Any basic action on the queue is inseparable (or atomic). That is, when any action is executed on the queue, no other action can be executed until the current action is finished.
- There may be unbounded number of agents.
- In the initial state, every agents are in the remainder section (or at the label `rm`), and the queue is empty.

The property to be shown is that at most one agent is in the critical section (or at the label `cs`) at any moment.

Modeling QLOCK (via Signature Diagram) with OTS (Observational Transition System)



Schematic signature diagram for OTS



Signature for QLOCKwithOTS

- `Sys` is the sort for representing the state space of the system.
- `Pid` is the sort for the set of agent/process names.
- `Label` is the sort for the set of labels; i.e. `{rm, wt, cs}`.
- `Queue` is the sort for the queues of `Pid`
- `pc` (program counter) is an observer returning a label where each agent resides.
- `queue` is an observer returning the current value of the waiting queue of `Pid`.
- `want` is an action for agent `i` of putting its name/id into the queue.
- `try` is an action for agent `i` of checking whether its name/id is at the top of the queue.
- `exit` is an action for agent `i` of removing/getting its name/id from the top of the queue.

CafeOBJ signature for QLOCKwithOTS

```
-- state space of the system
[Sys]

-- visible sorts for observation
[Queue Pid Label]

-- observations
op pc : Sys Pid -> Label
op queue : Sys -> Queue

-- any initial state
op init : -> Sys (constr)
-- actions
op want : Sys Pid -> Sys {constr}
op try  : Sys Pid -> Sys {constr}
op exit : Sys Pid -> Sys {constr}
```

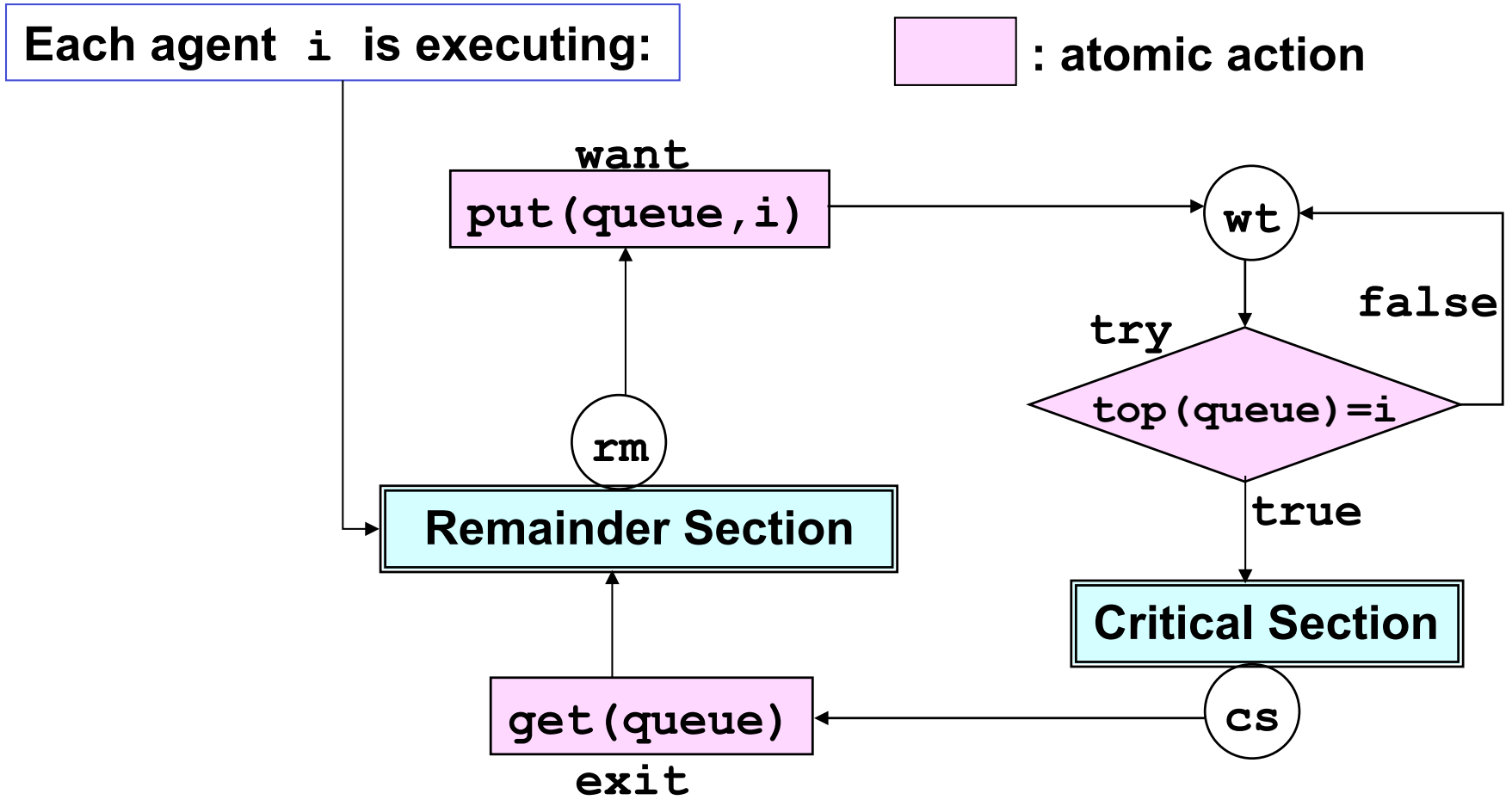
system sort declaration

visible sort declaration

observation declaration

action declaration

QLOCK using operators in the CafeOBJ module QUEUE



CafeOBJ Code in the file qlock.cafe (1)

```
mod! LABELconst
mod* LABLE
mod* PID*
mod* TRIV=
mod! QUEUE
```

CafeOBJ Code in the file qlock.cafe (2)

```
mod* QLOCK
```

(_ =*= _) is congruent for OTS

The binary relation `(S1:Sys =*= S2:Sys)` is defined to be true iff `S1` and `S2` have the same observation values.

OTS style of defining the possible changes of the values of obervations is characterized by the equations of the form:

$o(a(s,d),d') = \ldots o_1(s,d_1)\ldots o_2(s,d_2)\ldots o_n(s,d_n)\ldots$

for appropriate data values of $d, d', d_1, d_2, \ldots, d_n$.

It can be shown that OTS style guarantees that `(_ =*= _)` is congruent with respect to all actions.

R_{QLOCK} (set of reachable states) of OTS_{QLOCK} (OTS defined by the module QLOCK)

Signature determining R_{QLOCK} = Sys

```
-- initial state
  op init : -> Sys {constr}
-- actions
  bop want : Sys Pid -> Sys {constr}
  bop try  : Sys Pid -> Sys {constr}
  bop exit : Sys Pid -> Sys {constr}
```

Recursive definition of R_{QLOCK} = Sys

$$R_{QLOCK} = Sys = \{init\} \cup \{want(s,i) \mid s \in Sys, i \in Pid\} \cup \{try(s,i) \mid s \in Sys, i \in Pid\} \cup \{exit(s,i) \mid s \in Sys, i \in Pid\}$$

Mutual exclusion property as an invariant on R_{QLOCK} = Sys

invariants-0.mod

```
mod INV1 {
   inc(QLOCK)
-- declare a predicate to verify to be an invariant
   pred inv1 : Sys Pid Pid
-- variables
   var S :  Sys .
   vars I J : Pid .
-- define inv1 to be the mutual exclusion property
   eq inv1(S,I,J)
       = (((pc(S,I) = cs) and (pc(S,J) = cs)) implies I = J) .
}
```

Formulation of proof goal for mutual exclusion property

$$\mathtt{INV1} \models \forall s \in \mathtt{Sys}\, \forall i,j \in \mathtt{Pid}.\mathtt{inv1}(s,i,j)$$