UML-B State Machine Diagrams

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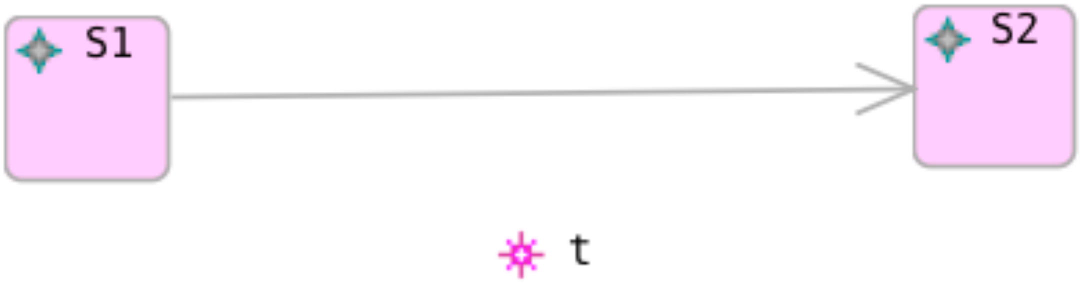
Colin Snook University of Southampton

State Machines

State machines provide a way to model behaviour (transitions)

Constrained by some data (source state)

The transition's behaviour is to change the data (to target state)

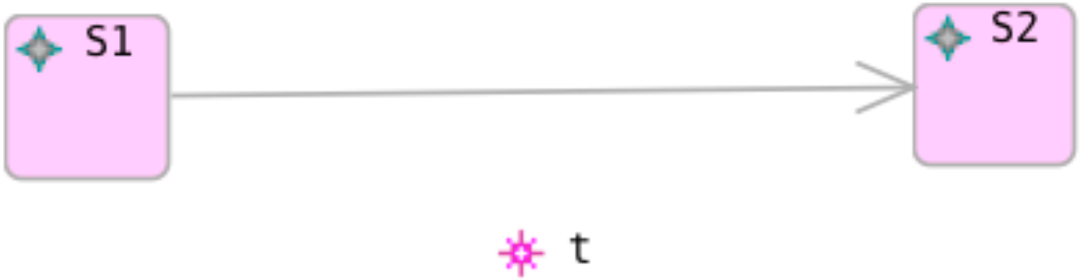


Transition t can only fire when the state is S1

when t fires it changes the state to S2

How could we represent this in Event-B?

State Machines to Events



EVENTS

t ≙ WHEN <in S1> THEN <becomes S2> END

where, <in S1> and <becomes S2> depend on the data that represents state

State machine as a type

We could treat the whole statemachine as an enumerated type

the current state is given by a variable

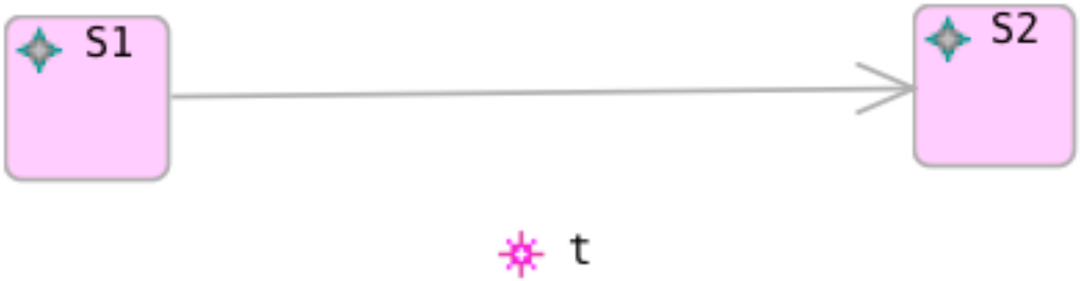
(called state_function translation in UML-B)

VARIABLES

sm : sm_STATES

SETS

sm_STATES = {S1,S2}



EVENTS

t ≙ WHEN <in S1> THEN <becomes S2> END

what are <in S1> and <becomes S2> in this case?

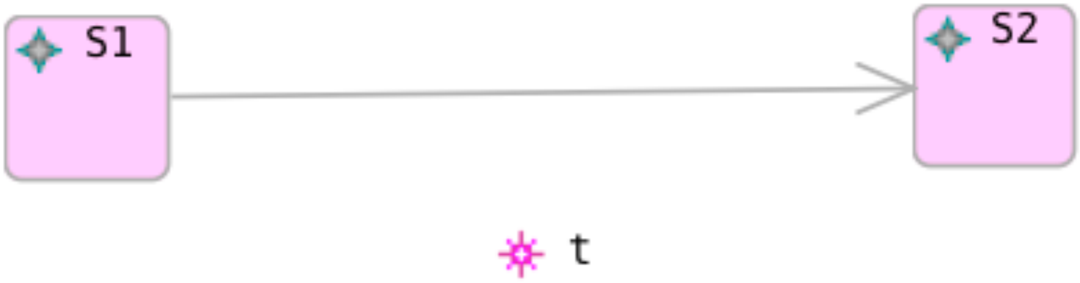
State machine as a type

VARIABLES

sm : sm_STATES

SETS

sm_STATES = {S1,S2}



EVENTS

t ≙ WHEN sm = S1 THEN sm := S2 END

State machine collection of variables

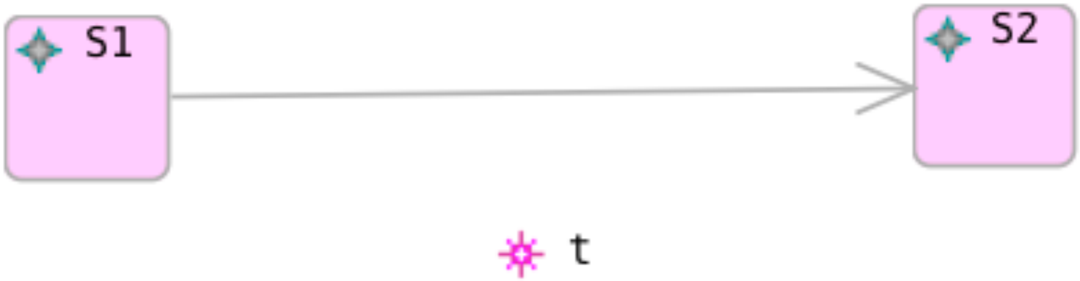
Or we could treat each state as a separate variable

(called state_sets translation in UML-B)

VARIABLES

S1 : BOOL

S2 : BOOL *where, one of S1, S2 is TRUE at any moment*



EVENTS

t ≙ WHEN <in S1> THEN <becomes S2> END

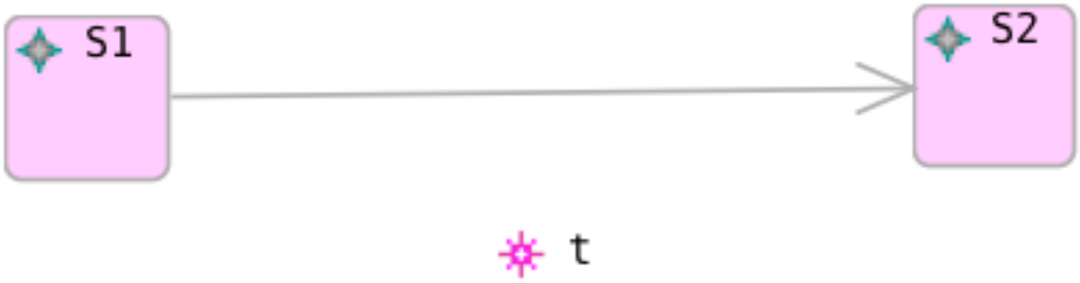
what are <in S1> and <becomes S2> in this case?

State machine collection of variables

VARIABLES

S1 : BOOL

S2 : BOOL



EVENTS

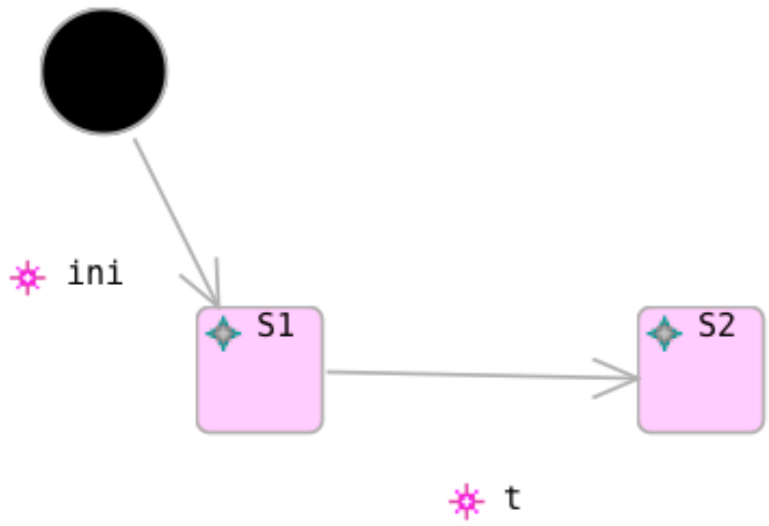
t ≙ WHEN S1 = TRUE

THEN S1 := FALSE

S2 := TRUE

END

Initial transition



Statemachine as type

INITIALISATION

sm := S1

States as variables

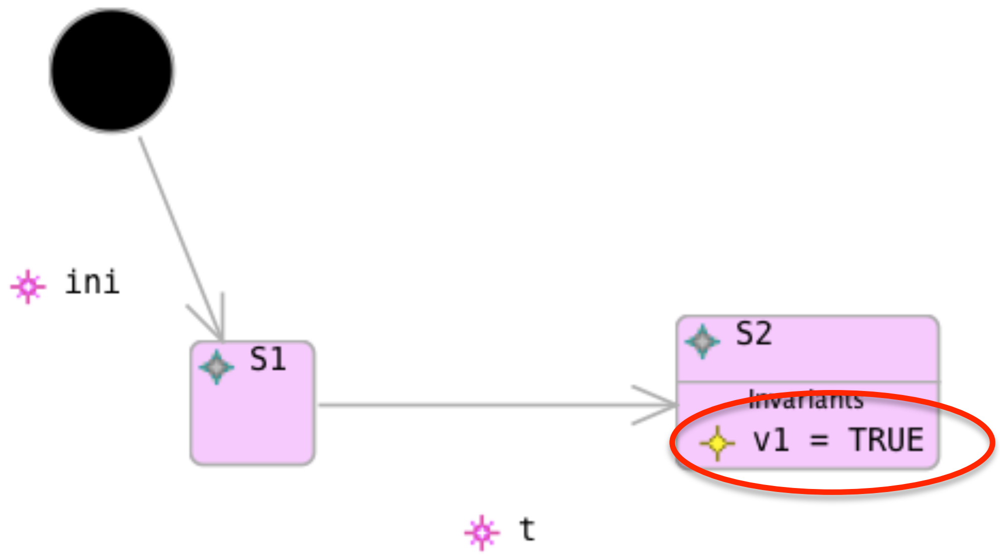
INITIALISATION

S1 := TRUE

S2 := FALSE

State Invariant

Something that must be true whenever the system is in that state.



Translations:

$$(sm = S2) \Rightarrow (v1 = TRUE)$$

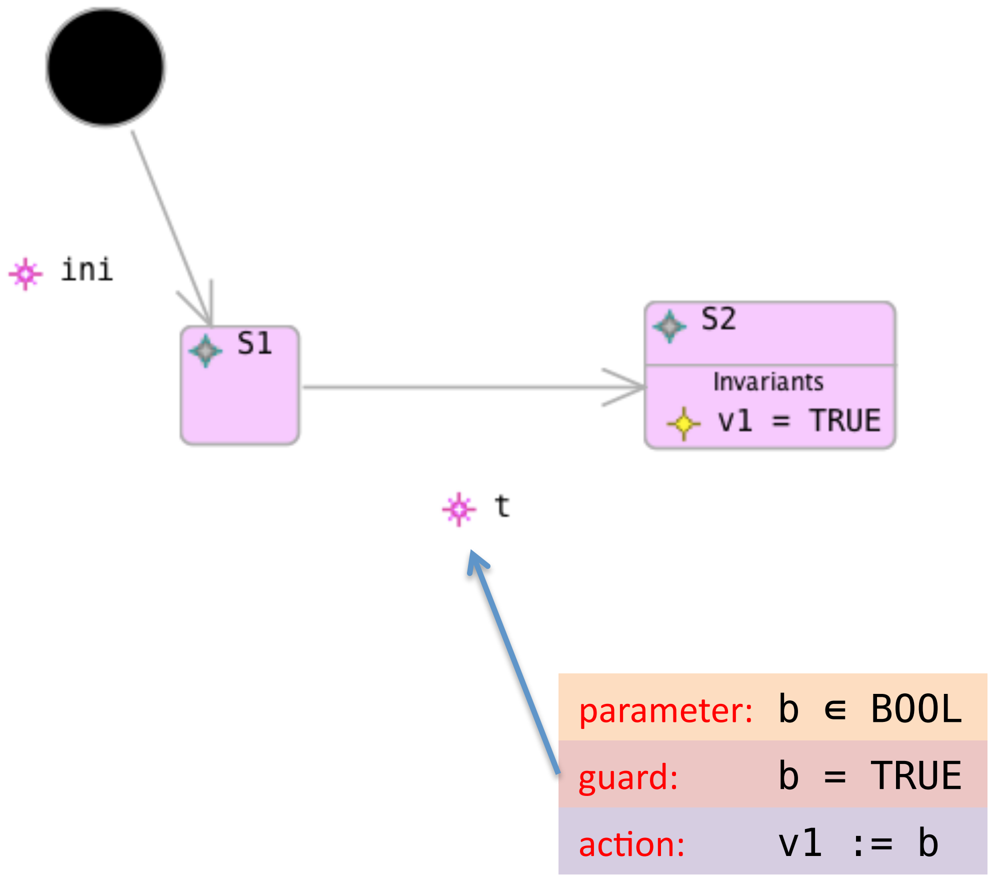
or

$$(S2{=}TRUE) \Rightarrow (v1 = TRUE)$$

Transition parameters, guards and actions

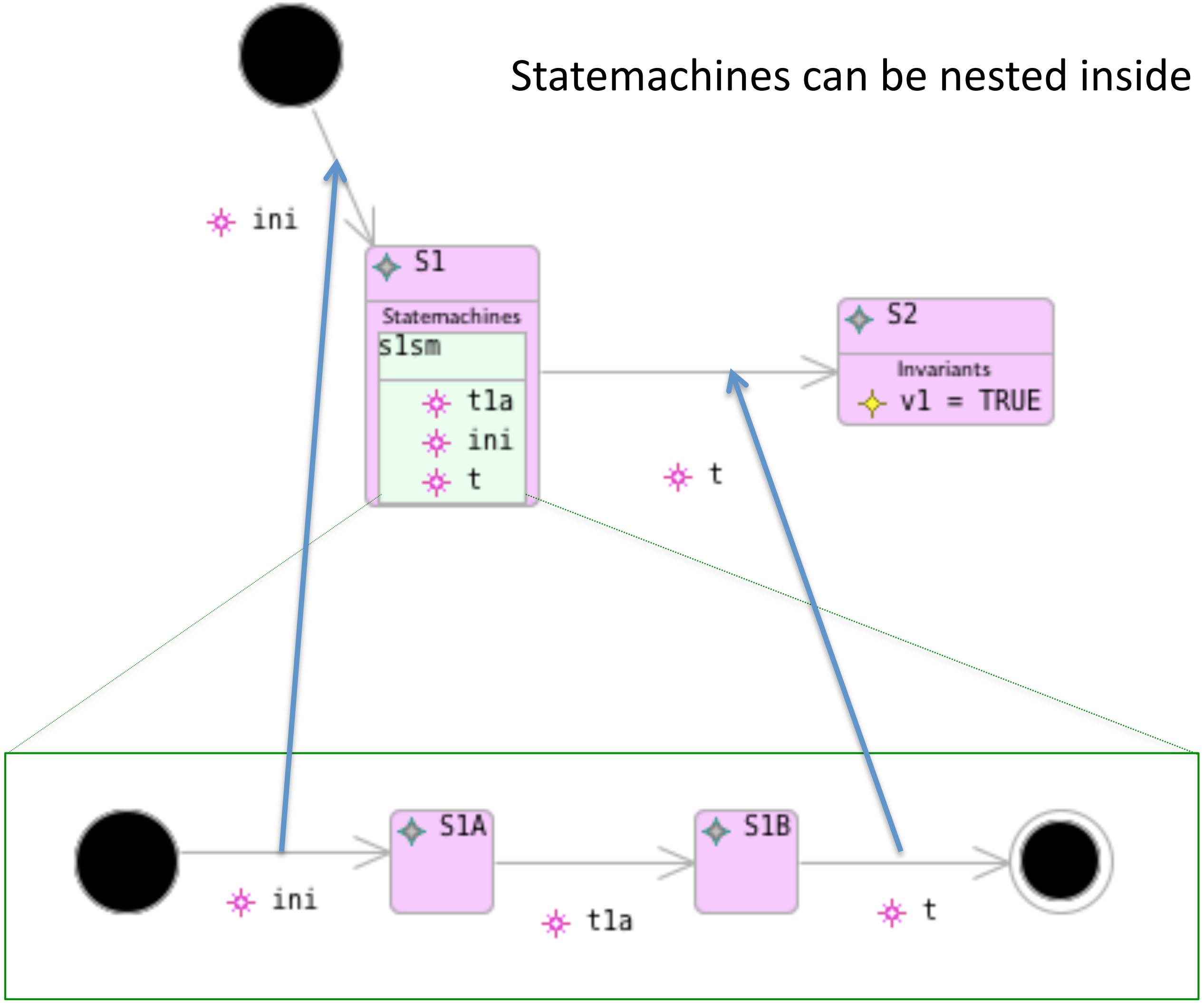
Transitions are events.

So you can give them parameters, guards and actions etc.



Nested Statemachines

Statemachines can be nested inside states



Entry and Exit transitions must align with parent state using Elaborates property

Example

A factory machine can be switched on and off.

When it is on it can then be started and becomes active.

When it is active it can run repeatedly until it is stopped.

A separately controlled guard mechanism can be opened and closed.

[The guard is opened automatically when the machine is stopped]

Safety Requirement:

The machine should never be in the active state (where runs can occur) with the guard in the open position.

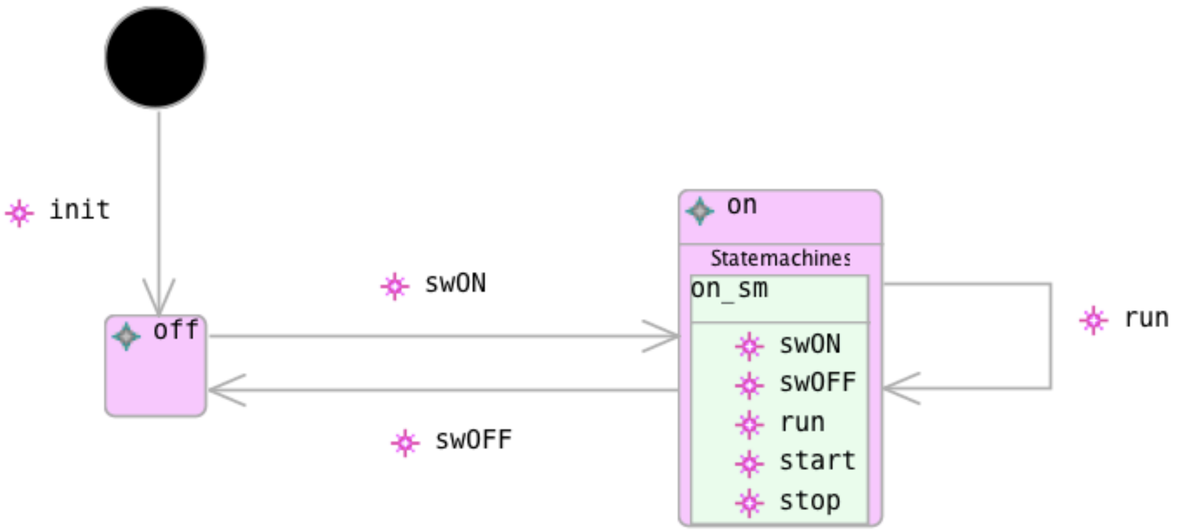
Model the machine and guard as separate statemachines.

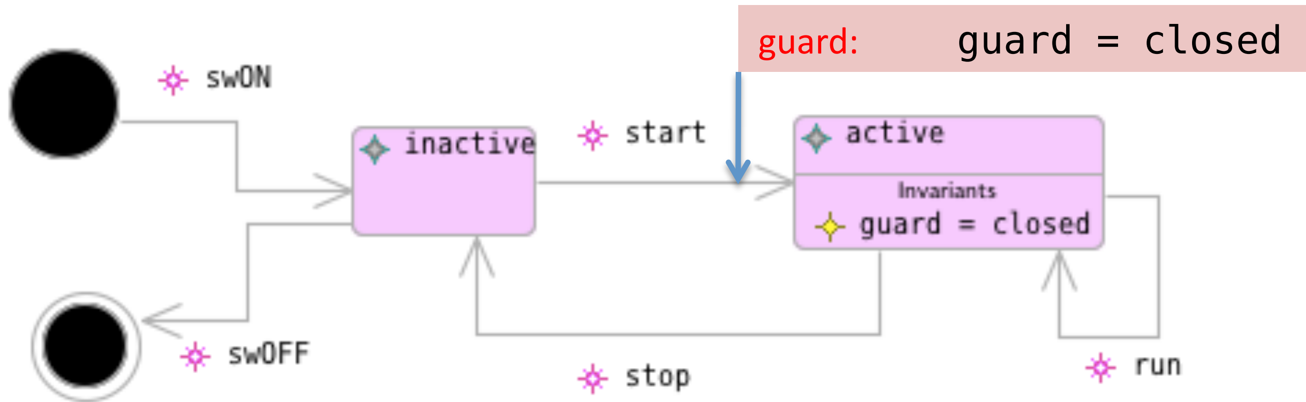
Add an invariant to model the safety requirement.

Determine the transitions guards needed to represent the interlocks between the machine and the guard controller.

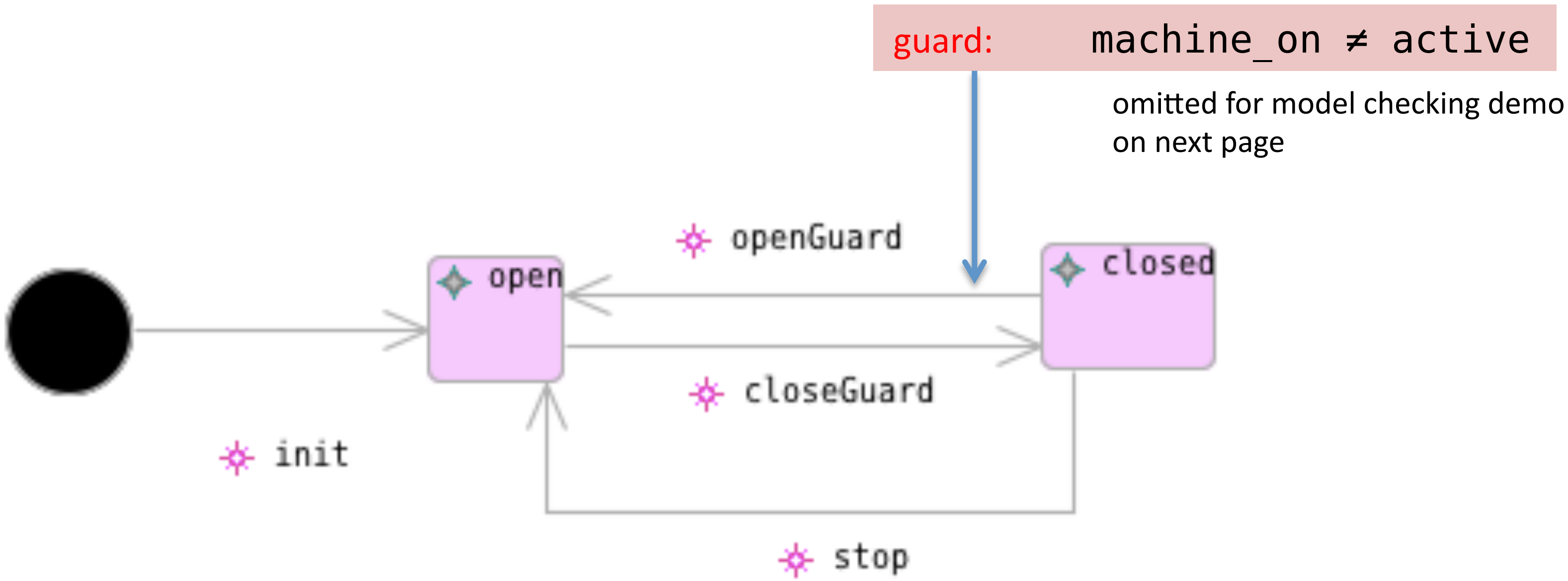
Use the Pro-B model checker/Animator to ensure that the safety invariant is never violated

Example – Factory Machine

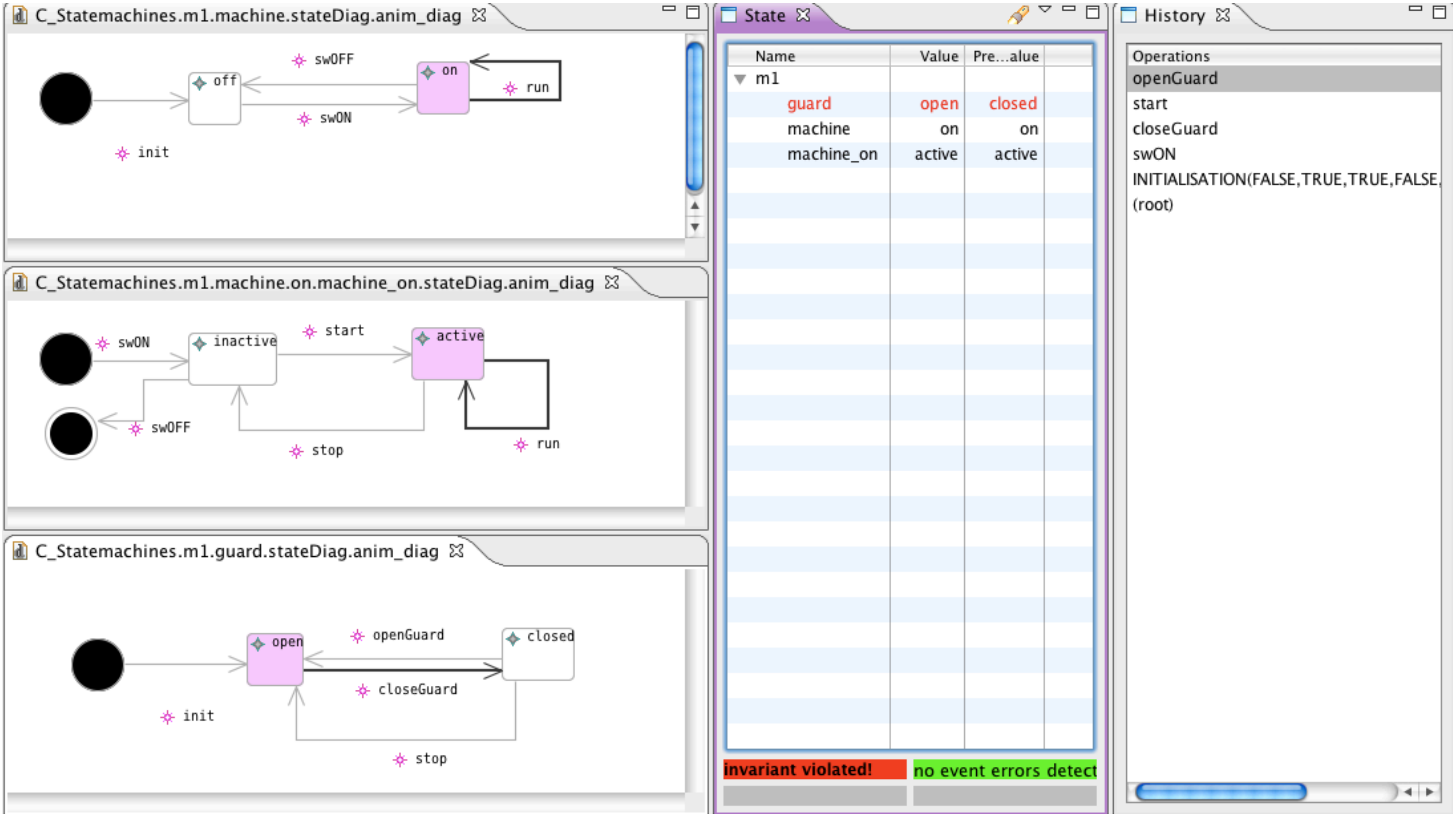




Example – Factory Machine Safety Guard



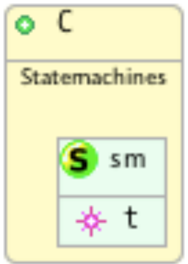
Statemachine Animation showing invariant violation



Statemachines in Classes

Statemachines can be added to classes.

Effectively, each class instance has a ''copy'' of the statemachine



State machines in Classes

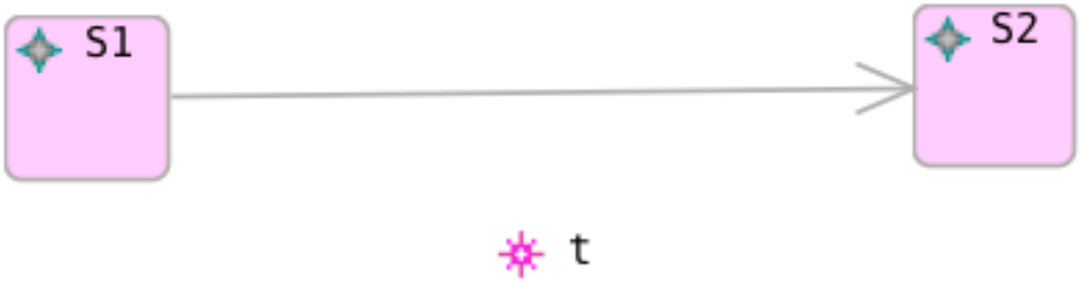
State machine as a type (state_function)

VARIABLES

$sm \in C \rightarrow sm\_STATES$

SETS

$sm\_STATES = \{S1,S2\}$



EVENTS

t (self) ≙ WHERE sm(self) = S1
THEN sm(self) := S2
END

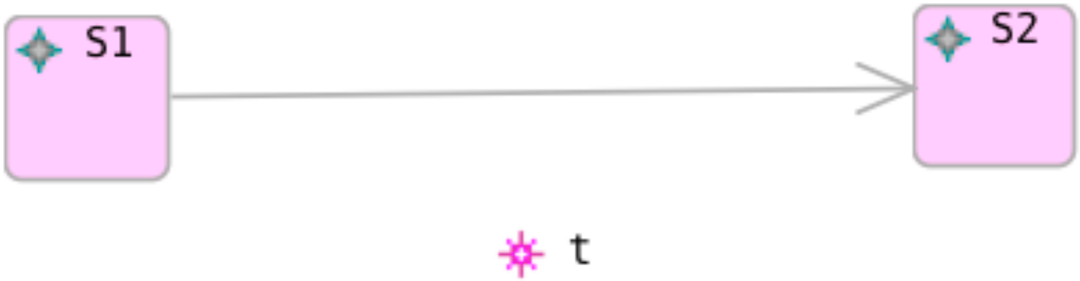
State machines in Classes

States as variables (state_sets)

VARIABLES

$S1 \in \mathbb{P}(C)$

$S2 \in \mathbb{P}(C)$ *where S1 and S2 (and….) are disjoint*



EVENTS

$t(self) \triangleq$ WHERE $self \in S1$

THEN $S1 := S1 \setminus \{self\}$

$S2 := S2 \cup \{self\}$

END

Initial transition (state_sets)

For variable instance classes, initial transition is treated as a constructor

```
ini ≙
STATUS
  ordinary
ANY
  self      //   constructed instance of class C
WHERE
  self.type   :   self ∈ C_SET \ C
THEN
  C_constructor    :   C ≔ C ∪ {self}
  sm_enterState_S1   :   S1 ≔ S1 ∪ {self}
END
```

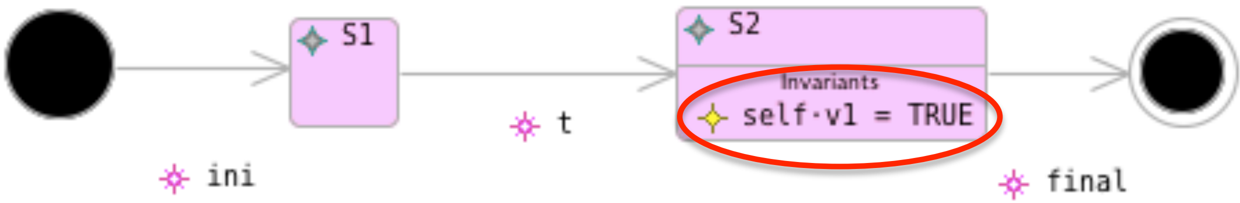
Final transition (state_sets)

For variable instance classes, final transition is treated as a destructor

```
final  ≙
STATUS
  ordinary
ANY
  self       //   contextual instance of class C
WHERE
  self.type    :   self ∈ C
  sm_isin_S2    :   self ∈ S2
THEN
  sm_leaveState_S2    :   S2 ≔ S2 \ {self}
  C_destructor    :   C ≔ C \ {self}
END
```

State Invariant (state_sets)

Something that must be true whenever an instance of the class is in that state.



Translation:

$$\forall self \cdot ((self \in C) \Rightarrow ((self \in S2) \Rightarrow (v1(self) = TRUE)))$$

Summary

Statemachines for modelling behaviour

- nested – statemachines in states
- invariants in states
- transitions are events (with parameters, guards, actions)

Choice of 2 translations

Can be lifted to classes

- initial/final transition as constructor/destructor (variable instance classes)

State-machines can be animated and model checked

- (front-end for Pro-B)