MACHINE Stable_Pendule
REFINES StableLassaleGeneric
SEES PenduleCtx
VARIABLES

t
x
dx
cos_th
sin_th
dtheta
x_s

INVARIANTS

inv1: $x \in RReal \nrightarrow RReal$
inv2: $dx \in RReal \nrightarrow RReal$
inv3: $cos\_th \in RReal \nrightarrow RReal$
inv4: $sin\_th \in RReal \nrightarrow RReal$
inv5: $dtheta \in RReal \nrightarrow RReal$
inv11: $Closed2Closed(Rzero, t) \subseteq dom(x)$
inv21: $dom(x) = dom(dx)$
inv31: $dom(x) = dom(cos\_th)$
inv41: $dom(x) = dom(sin\_th)$
inv51: $dom(x) = dom(dtheta)$
inv7: $x\_p = bind(bind(bind(bind(x, dx), cos\_th), sin\_th), dtheta)$

EVENTS
Initialisation
with
x_p': $x\_p' = bind(bind(bind(bind(x', dx'), cos\_th'), sin\_th'), dtheta')$
begin
act1: $t := Rzero$
act2:
$x, dx, cos\_th, sin\_th, dtheta :=$
$Rfcste(Rzero),$
$Rfcste(Rzero),$
$Rfcste(cos(angle\_init)),$
$Rfcste(sin(angle\_init)),$
$Rfcste(Rzero)$
act3: $x\_s := etat$
end
Event Transition ⟨ordinary⟩ $\widehat{=}$
refines Transition
any
s
where
grd2: $s = \{etat\}$
then
act1: $x\_s := etat$
end
Event Sense ⟨ordinary⟩ $\widehat{=}$
refines Sense
with
s: $s = \{etat\}$
p: $p = STATES \times RReal \times \{x\_ \mapsto dx\_ \mapsto cos\_ \mapsto sin\_ \mapsto dth\_ | (x\_ \mapsto dx\_ \mapsto cos\_ \mapsto sin\_ \mapsto dth\_) \in S\}$
begin
act1: $x\_s := etat$

end

Event Actuate ⟨ordinary⟩ $\widehat{=}$

refines Actuate

any

tp

where

grd0: $tp \in RRealPlus \land t \mapsto tp \in lt$

grd2:

$Solvable(Closed2Closed(t, tp), ode(F,$
$bind(bind(bind(bind(x, dx), cos\_th), sin\_th), dtheta)(Rzero), Rzero))$

grd4: $x\_s = etat$

grd7: $tp \in RRealPlus \land t \mapsto tp \in lt$

with

e: $e = ode(F, x\_p(Rzero), Rzero)$

s: $s = \{etat\}$

x_p': $x\_p' = bind(bind(bind(bind(x', dx'), cos\_th'), sin\_th'), dtheta')$

then

act1:

$t, x, dx, cos\_th, sin\_th, dtheta :|$
$(t' = tp \land$
$x' \in RReal \rightarrowtail\!\!\!\!\!\!+ RReal \land Closed2Closed(Rzero, t') = dom(x') \land x'(t) = x(t) \land$
$dx' \in RReal \rightarrowtail\!\!\!\!\!\!+ RReal \land Closed2Closed(Rzero, t') = dom(dx') \land dx'(t) = dx(t) \land$
$cos\_th' \in RReal \rightarrowtail\!\!\!\!\!\!+ RReal \land Closed2Closed(Rzero, t') = dom(cos\_th') \land cos\_th'(t) = cos\_th(t) \land$
$sin\_th' \in RReal \rightarrowtail\!\!\!\!\!\!+ RReal \land Closed2Closed(Rzero, t') = dom(sin\_th') \land sin\_th'(t) = sin\_th(t) \land$
$dtheta' \in RReal \rightarrowtail\!\!\!\!\!\!+ RReal \land Closed2Closed(Rzero, t') = dom(dtheta') \land dtheta'(t) = dtheta(t) \land$
$CBAPsolutionOf(t, t',$
$bind(bind(bind(bind(x, dx), cos\_th), sin\_th), dtheta), bind(bind(bind(bind(x', dx'), cos\_th'), sin\_th'), dtheta'),$
$ode(F, bind(bind(bind(bind(x, dx), cos\_th), sin\_th), dtheta)(Rzero), Rzero),$
$Closed2Closed(t, t') \times S)$
$)$

end

Event Behave ⟨ordinary⟩ $\widehat{=}$

Refining Behave exactly as Actuate

refines Behave

any

tp

where

grd0: $tp \in RRealPlus \land t \mapsto tp \in lt$

grd2:

$Solvable(Closed2Closed(t, tp), ode(F,$
$bind(bind(bind(bind(x, dx), cos\_th), sin\_th), dtheta)(Rzero), Rzero))$

with

e: $e = ode(F, x\_p(Rzero), Rzero)$

Inv: $Inv = Closed2Closed(t, t') \times S$

x_p': $x\_p' = bind(bind(bind(bind(x', dx'), cos\_th'), sin\_th'), dtheta')$

then

act1:

$t, x, dx, cos\_th, sin\_th, dtheta :|$
$(t' = tp \land$
$x' \in RReal \rightarrowtail\!\!\!\!\!\!+ RReal \land Closed2Closed(Rzero, t') = dom(x') \land x'(t) = x(t) \land$
$dx' \in RReal \rightarrowtail\!\!\!\!\!\!+ RReal \land Closed2Closed(Rzero, t') = dom(dx') \land dx'(t) = dx(t) \land$
$cos\_th' \in RReal \rightarrowtail\!\!\!\!\!\!+ RReal \land Closed2Closed(Rzero, t') = dom(cos\_th') \land cos\_th'(t) = cos\_th(t) \land$
$sin\_th' \in RReal \rightarrowtail\!\!\!\!\!\!+ RReal \land Closed2Closed(Rzero, t') = dom(sin\_th') \land sin\_th'(t) = sin\_th(t) \land$
$dtheta' \in RReal \rightarrowtail\!\!\!\!\!\!+ RReal \land Closed2Closed(Rzero, t') = dom(dtheta') \land dtheta'(t) = dtheta(t) \land$
$CBAPsolutionOf(t, t',$
$bind(bind(bind(bind(x, dx), cos\_th), sin\_th), dtheta), bind(bind(bind(bind(x', dx'), cos\_th'), sin\_th'), dtheta'),$
$ode(F, bind(bind(bind(bind(x, dx), cos\_th), sin\_th), dtheta)(Rzero), Rzero),$
$Closed2Closed(t, t') \times S)$
$)$

end

END