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1 MACHINE
2   Car_M1
3 REFINES
4   ControlledSystem
5 SEES
6   Car_C1
7 VARIABLES  $t, x_s, v, x$ 
8 INVARIANTS
9    $inv1: v \in RRealPlus \rightarrow RReal$ 
10   $inv2: x \in RRealPlus \rightarrow RReal$ 
11   $inv3: x_p = bind(v, x)$ 
12   $inv4: \forall t0 \cdot t0 \in RRealPlus \Rightarrow Rzero \mapsto v(t0) \in leq$ 
13   $inv5: \forall t0 \cdot t0 \in RRealPlus \wedge x_s = stopped \Rightarrow x(t0) \mapsto SP \in leq$ 
14 EVENTS
15 INITIALISATION
16 WITH
17    $x_p': x_p' = bind(v', x')$ 
18 THEN
19   act1:  $t := Rzero$ 
20   act2:
21      $v, x: |$ 
22      $x' \in RRealPlus \rightarrow RReal \wedge v' \in RRealPlus \rightarrow RReal \wedge$ 
23      $solutionOf(RRealPlus, bind(v', x'), ode(f\_stable, (v0 \mapsto Rzero), Rzero))$ 
24   act3:  $x_s := stabilizing$ 
25 END
26
27 Progress
28 REFINES Progress
29 THEN
30   act1:  $t: | t' \in RRealPlus \wedge (t \mapsto t' \in lt)$ 
31 END
32
33 Behave
34 REFINES Behave
35 ANY e
36 WHERE
37   grd1:  $e \in DE(S)$ 
38   grd2:  $Solvable(Closed2Infinity(t), e)$ 
39 WITH
40    $x_p': x_p' = bind(v', x')$ 
41 THEN
42   act1:
43      $v, x: |$ 
44      $x' \in RRealPlus \rightarrow RReal \wedge v' \in RRealPlus \rightarrow RReal \wedge$ 
45      $AppendSolutionBAP($ 
46        $e,$ 
47        $RRealPlus,$ 
48        $Closed2Open(Rzero, t), Closed2Infinity(t),$ 
49        $bind(v, x), bind(v', x')$ 
50      $)$ 
51 END
52
53 Transition
54 REFINES Transition
55 ANY s
56 WHERE
57   grd1:  $s \in \mathbb{P}1(STATES)$ 
58 THEN
59   act1:  $x_s \in s$ 
60 END
61
62 ctrl_sense_near_stop
63 REFINES Sense
64 WHERE
65   grd1:  $plus(x(t) \mapsto divide(times(v(t) \mapsto v(t)) \mapsto times(Rtwo \mapsto b))) \mapsto SP \in geq$ 
66   grd2:  $v(t) \mapsto Rzero \in gt$ 
67 WITH
68    $s: s = \{nearing\_stop\}$ 
69    $p:$ 
70      $p = STATES \times RReal \times \{v\_ \mapsto x\_ | plus(x\_ \mapsto divide(times(v\_ \mapsto v\_)) \mapsto times(Rtwo \mapsto b))) \mapsto SP \in geq \wedge v\_ \mapsto Rzero \in gt\}$ 
71 THEN
72   act1:  $x_s := nearing\_stop$ 

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72  END
73
74  ctrl_sense_stopping
75  REFINES Sense
76  WHERE
77    grd1:  $v(t) = Rzero$ 
78  WITH
79    s:  $s = \{stabilizing, stopped\}$ 
80    p:  $p = STATES \times RReal \times \{v\_ \mapsto x\_ \mid v\_ = Rzero \wedge x\_ \in RReal\}$ 
81  THEN
82    act1:
83       $x\_s :|$ 
84         $(x\_s = nearing\_stop \Rightarrow x\_s' = stopped) \wedge$ 
85         $(x\_s \neq nearing\_stop \Rightarrow x\_s' = stabilizing)$ 
86  END
87
88  ctrl_sense_user_input_accelerate
89  REFINES Sense
90  WHERE
91    grd1:  $plus(x(t) \mapsto divide(times(v(t) \mapsto v(t)) \mapsto times(Rtwo \mapsto b))) \mapsto SP \in lt$ 
92  WITH
93    s:  $s = \{accelerating\}$ 
94    p:  $p = STATES \times RReal \times \{v\_ \mapsto x\_ \mid plus(x\_ \mapsto divide(times(v\_ \mapsto v\_)) \mapsto times(Rtwo \mapsto b))) \mapsto SP \in lt\}$ 
95  THEN
96    act1:  $x\_s := accelerating$ 
97  END
98
99  ctrl_sense_user_input_stabilize
100 REFINES Sense
101 WHERE
102   grd1:  $plus(x(t) \mapsto divide(times(v(t) \mapsto v(t)) \mapsto times(Rtwo \mapsto b))) \mapsto SP \in lt$ 
103 WITH
104   s:  $s = \{stabilizing\}$ 
105   p:  $p = STATES \times RReal \times \{v\_ \mapsto x\_ \mid plus(x\_ \mapsto divide(times(v\_ \mapsto v\_)) \mapsto times(Rtwo \mapsto b))) \mapsto SP \in lt\}$ 
106 THEN
107   act1:  $x\_s := stabilizing$ 
108 END
109
110 ctrl_sense_user_input_brake
111 REFINES Sense
112 WHERE
113   grd1:  $v(t) \mapsto Rzero \in gt$ 
114 WITH
115   s:  $s = \{braking\}$ 
116   p:  $p = STATES \times RReal \times \{v\_ \mapsto x\_ \mid v\_ \mapsto Rzero \in gt \wedge x\_ \in RReal\}$ 
117 THEN
118   act1:  $x\_s := braking$ 
119 END
120
121 ctrl_actuate_brake
122 REFINES Actuate
123 WHERE
124   grd1:  $x\_s \in \{braking, nearing\_stop\}$ 
125 WITH
126   e:  $e = ode(f\_deceleration(t \mapsto v(t)), (v(t) \mapsto x(t)), t)$ 
127   s:  $s = \{braking, nearing\_stop\}$ 
128    $x\_p' : x\_p' = bind(v', x')$ 
129 THEN
130   act1:
131      $v, x :|$ 
132        $x' \in RRealPlus \rightarrow RReal \wedge v' \in RRealPlus \rightarrow RReal \wedge$ 
133        $AppendSolutionBAP($ 
134          $ode(f\_deceleration(t \mapsto v(t)), (v(t) \mapsto x(t)), t),$ 
135          $RRealPlus,$ 
136          $Closed2Open(Rzero, t), Closed2Infinity(t),$ 
137          $bind(v, x), bind(v', x')$ 
138       )
139 END
140
141 ctrl_actuate_accelerate
142 REFINES Actuate
143 WHERE
144   grd1:  $x\_s = accelerating$ 
145 WITH

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146   e: e = ode(f_acceleration, (v(t) ↦ x(t)), t)
147   s: s = {accelerating}
148   x_p': x_p' = bind(v', x')
149 THEN
150   act1:
151     v, x:|
152     x' ∈ RRealPlus → RReal ∧ v' ∈ RRealPlus → RReal ∧
153     AppendSolutionBAP(
154       ode(f_acceleration, (v(t) ↦ x(t)), t),
155       RRealPlus,
156       Closed2Open(Rzero, t), Closed2Infinity(t),
157       bind(v, x), bind(v', x')
158     )
159 END
160
161 ctrl_actuate_stabilize
162 REFINES Actuate
163 WHERE
164   grd1: x_s ∈ {stabilizing, stopped}
165 WITH
166   e: e = ode(f_stable, (v(t) ↦ x(t)), t)
167   s: s = {stabilizing, stopped}
168   x_p': x_p' = bind(v', x')
169 THEN
170   act1:
171     v, x:|
172     x' ∈ RRealPlus → RReal ∧ v' ∈ RRealPlus → RReal ∧
173     AppendSolutionBAP(
174       ode(f_stable, (v(t) ↦ x(t)), t),
175       RRealPlus,
176       Closed2Open(Rzero, t), Closed2Infinity(t),
177       bind(v, x), bind(v', x')
178     )
179 END
180
181 END

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