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1 MACHINE
2   Robot_2
3 REFINES
4   Robot_1
5 SEES
6   Robot_2_Ctx
7 VARIABLES  $t, Target, DirectionControl, vC, pC$ 
8 INVARIANTS
9   inv1 :  $DirectionControl \in \mathbb{R} \times \mathbb{R}$ 
10  inv2 :  $DeltaNeighborhood(ControllerSpeedLimit, DirectionControl, 0 \mapsto 0)$ 
11  inv3 :  $pC \in \mathbb{R} \mapsto S$ 
12  inv6 :  $[0, t] \subseteq dom(pC)$ 
13  inv7 :  $vC \in \mathbb{R} \mapsto S$ 
14  inv8 :  $[0, t] \subseteq dom(vC)$ 
15  inv11 :  $Direction = DirectionControl$ 
16  inv12 :  $DeltaApproximation([0, t], AppDelta, pA, pC)$ 
17  inv13 :  $\forall t_-. t_- \in [0, t] \Rightarrow plannar\_distance(pC(t_-), 0 \mapsto 0) \mapsto minus(CriticalDistance \mapsto AppDelta) \in lt$ 
18 EVENTS
19 INITIALISATION
20 THEN
21   act1 :  $t := 0$ 
22   act3 :  $pC := \{0 \mapsto (px0 \mapsto py0)\}$ 
23   act4 :  $vC := \{0 \mapsto (0 \mapsto 0)\}$ 
24   act5 :  $Target :| Target' \in \mathbb{R} \times \mathbb{R} \wedge plannar\_distance(Target', 0 \mapsto 0) \mapsto minus(CriticalDistance \mapsto CloseEnough) \in lt$ 
25   act6 :  $DirectionControl := 0 \mapsto 0$ 
26 END
27
28 Behave
29 REFINES Behave
30 ANY  $e2, tp$ 
31 WHERE
32   grd1 :  $e2 \in DE(S2)$ 
33   grd2 :  $Solvable([t, tp], e2)$ 
34   grd3 :  $plannar\_distance(Target, pC(t)) \mapsto plus(CloseEnough \mapsto AppDelta) \in gt$ 
35   grd4 :  $tp \in \mathbb{R}^+$ 
36   grd5 :  $t < tp$ 
37   grd6 :
38      $CBAPSolutionOfFIS(t, tp, [vC pC]^T, e2, \{(vx_- \mapsto vy_-) \mapsto (px_- \mapsto py_-) \mid plannar\_distance(Target, px_- \mapsto py_-) \mapsto CloseEnough \in gt\})$ 
39 WITH
40   e :
41      $e \in DE(S) \wedge$ 
42      $Solvable([t, t'], e) \wedge$ 
43      $\forall etaA, etaC.$ 
44        $etaA \in \mathbb{R}^+ \mapsto S \wedge etaC \in \mathbb{R}^+ \mapsto S2 \wedge$ 
45        $[0, t'] \subseteq dom(etaA) \wedge$ 
46        $[0, t'] \subseteq dom(etaC) \wedge$ 
47        $solutionOf([t, t'], etaA, e) \wedge$ 
48        $solutionOf([t, t'], etaC, e2) \Rightarrow$ 
49          $DeltaApproximation([t, t'], AppDelta, etaA, fproj2(etaC))$ 
50     )
51    $pA' :$ 
52      $pA' \in \mathbb{R} \mapsto S \wedge [0, t'] \subseteq dom(pA') \wedge$ 
53      $DeltaApproximation([0, t'], AppDelta, pA', pC')$ 
54 THEN
55   act1 :
56      $t, pC, vC :|$ 
57      $pC' \in \mathbb{R} \mapsto S \wedge$ 
58      $vC' \in \mathbb{R} \mapsto S \wedge$ 
59      $t' = tp \wedge$ 
60      $[0, t'] \subseteq dom(pC') \wedge$ 
61      $[0, t'] \subseteq dom(vC') \wedge$ 
62      $CBAPSolutionOf(f(t, t', [vC pC]^T, [vC' pC']^T, e2, \{(vx_- \mapsto vy_-) \mapsto (px_- \mapsto py_-) \mid plannar\_distance(Target, px_- \mapsto py_-) \mapsto CloseEnough \in gt\})$ 
63
64 END
65
66 sense_close_enough
67 REFINES sense_close_enough
68 ANY  $next\_direction\_ctrl, next\_target$ 
69 WHERE
70   grd1 :  $next\_direction\_ctrl \in \mathbb{R} \times \mathbb{R}$ 
71   grd2 :  $next\_target \in \mathbb{R} \times \mathbb{R}$ 
72   grd3 :  $plannar\_distance(Target, pC(t)) \mapsto minus(CloseEnough \mapsto AppDelta) \in leq$ 
73   grd4 :  $DeltaNeighborhood(ControllerSpeedLimit, 0 \mapsto 0, next\_direction\_ctrl)$ 

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72     grd5: plannar_distance(next_target, 0  $\mapsto$  0)  $\mapsto$  minus(CriticalDistance  $\mapsto$  CloseEnough)  $\in$  It
73 WITH
74     next_direction: next_direction = next_direction_ctrl
75 THEN
76     act1: DirectionControl := next_direction_ctrl
77     act2: Target := next_target
78 END
79
80 transition_change_direction
81 REFINES transition_change_direction
82 ANY new_direction_ctrl
83 WHERE
84     grd1: new_direction_ctrl  $\in$   $\mathbb{R} \times \mathbb{R}$ 
85     grd2: DeltaNeighborhood(ControllerSpeedLimit, 0  $\mapsto$  0, new_direction_ctrl)
86 WITH
87     new_direction: new_direction = new_direction_ctrl
88 THEN
89     act1: DirectionControl := new_direction_ctrl
90 END
91
92 transition_change_target
93 REFINES transition_change_target
94 END
95
96 actuate_movement
97 REFINES actuate_movement
98 ANY tp
99 WHERE
100     grd1: plannar_distance(Target, pC(t))  $\mapsto$  plus(CloseEnough  $\mapsto$  AppDelta)  $\in$  gt
101     grd7: tp  $\in$   $\mathbb{R}^+$ 
102     grd8: t < tp
103     grd9:
104         CBAPSolutionOfFIS(t, tp, [vC pC]T,
105             withControl(
106                 [t, tp],
107                 SecondOrder2DimensionSystem(
108                     ControlCoefficient,
109                     DeltaNeighborhoodSet(ControllerSpeedLimit, 0  $\mapsto$  0)  $\times$  ( $\mathbb{R} \times \mathbb{R}$ ),
110                     t,
111                     vC(t)  $\mapsto$  pC(t)
112                 ),
113                 PointwiseSlopedControl(
114                     [t, tp],
115                     prj1(DirectionControl), prj2(DirectionControl),
116                     t
117                 )
118             )
119         , {(vC_  $\mapsto$  pC_ ) | plannar_distance(Target, pC_ )  $\mapsto$  plus(CloseEnough  $\mapsto$  AppDelta)  $\in$  gt}
120 WITH
121     pA':
122         pA'  $\in$   $\mathbb{R} \rightarrow S \wedge$ 
123         [0, t']  $\subseteq$  dom(pA')  $\wedge$ 
124         CBAPSolutionOf(
125             t, t',
126             pA, pA',
127             withControl(
128                 [t, t'],
129                 FirstOrder2DimensionSystem(DeltaNeighborhoodSet(SpeedLimit, 0  $\mapsto$  0), t, pA(t)),
130                 PointwiseControl([t, t'], prj1(Direction), prj2(Direction), t)
131             ),
132             {px_  $\mapsto$  py_ | plannar_distance(Target, px_  $\mapsto$  py_ )  $\mapsto$  CloseEnough  $\in$  gt}
133         )  $\wedge$ 
134         DeltaApproximation([0, t'], AppDelta, pA', pC')
135 THEN
136     act1:
137         t, pC, vC :|
138         pC'  $\in$   $\mathbb{R} \rightarrow S \wedge$ 
139         vC'  $\in$   $\mathbb{R} \rightarrow S \wedge$ 
140         t' = tp  $\wedge$ 
141         [0, t']  $\subseteq$  dom(pC')  $\wedge$ 
142         [0, t']  $\subseteq$  dom(vC')  $\wedge$ 
143         CBAPSolutionOf(
144             t, t',
145             [vC pC]T,

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146 [vC' pC']T,
147 withControl(
148   [t, t'],
149   SecondOrder2DimensionSystem(
150     ControlCoefficient,
151     DeltaNeighborhoodSet(ControllerSpeedLimit, 0 ↦ 0) × (ℝ × ℝ),
152     t,
153     vC(t) ↦ pC(t)
154   ),
155   PointwiseSlopedControl(
156     [t, t'],
157     prj1(DirectionControl), prj2(DirectionControl),
158     t
159   )
160 ),
161 {(vC_ ↦ pC_) | plannar_distance(Target, pC_) ↦ plus(CloseEnough ↦ AppDelta) ∈ gt}
162 )
163 END
164
165 END
```