# Hybrid semantics of SRanger

Alvaro Miyazawa Ana Cavalcanti

$cycle : \mathbb{N};\ tscale : \mathbb{R}$

$cycle > 0 \land tscale > 0$
$cycle = 1$

**process** $SRanger \mathrel{\widehat=}$ **begin**

$LHinge\_AXIS : \mathbb{R}^3;\ LHinge\_S : \mathbb{R}^6;\ LHinge\_A : \mathbb{R}^6$
$LHinge\_T : \mathbb{R} \to \mathbb{R}^{4\times 4};\ LHinge\_AdT : \mathbb{R} \to \mathbb{R}^{6\times 6}$
$LHinge\_LMotor\_b : \mathbb{R};\ LHinge\_LMotor\_Ke : \mathbb{R};\ LHinge\_LMotor\_Kt : \mathbb{R}$
$LHinge\_LMotor\_R : \mathbb{R};\ LHinge\_LMotor\_L : \mathbb{R}$
$LHinge\_LMotor\_Kp : \mathbb{R};\ LHinge\_LMotor\_Ki : \mathbb{R};\ LHinge\_LMotor\_Kd : \mathbb{R}$
$RHinge\_AXIS : \mathbb{R}^3;\ RHinge\_S : \mathbb{R}^6;\ RHinge\_A : \mathbb{R}^6$
$RHinge\_T : \mathbb{R} \to \mathbb{R}^{4\times 4};\ RHinge\_AdT : \mathbb{R} \to \mathbb{R}^{6\times 6}$
$RHinge\_RMotor\_b : \mathbb{R};\ RHinge\_RMotor\_Ke : \mathbb{R};\ RHinge\_RMotor\_Kt : \mathbb{R}$
$RHinge\_RMotor\_R : \mathbb{R};\ RHinge\_RMotor\_L : \mathbb{R}$
$RHinge\_RMotor\_Kp : \mathbb{R};\ RHinge\_RMotor\_Ki : \mathbb{R};\ RHinge\_RMotor\_Kd : \mathbb{R}$

$LHinge\_AXIS = (0, 1, 0)$
$LHinge\_S = ScrewAxis(LHinge\_AXIS, Pitch :: Finite(0))$
$LHinge\_A = [Ad(AbsTransform((\frac{\mathscr{L}}{4}, \frac{\mathscr{W}}{2} + \frac{\mathscr{R}}{4} + 0.5cm, \mathscr{R}, 0, \frac{\pi}{2}, \frac{\pi}{2}))^{-1})] * LHinge\_S$
$LHinge\_T = \lambda\, \theta : \mathbb{R} \bullet e^{[LHinge\_A]*(-\theta)} * Transform((\frac{\mathscr{L}}{4}, \frac{\mathscr{W}}{2} + \frac{\mathscr{R}}{4} + 0.5cm, \mathscr{R}, 0, \frac{\pi}{2}, \frac{\pi}{2}), (0, 0, \frac{3\mathscr{R}}{4} + \frac{\mathscr{H}}{2}, 0, 0, 0))$
$LHinge\_AdT = \lambda\, \theta : \mathbb{R} \bullet [Ad(LHinge\_T(\theta))]$
$RHinge\_AXIS = (0, 1, 0)$
$RHinge\_S = ScrewAxis(RHinge\_AXIS, Pitch :: Finite(0))$
$RHinge\_A = [Ad(AbsTransform((\frac{\mathscr{L}}{4}, -(\frac{\mathscr{W}}{2} + \frac{\mathscr{R}}{4} + 0.5cm), \mathscr{R}, 0, \frac{\pi}{2}, \frac{\pi}{2}))^{-1})] * RHinge\_S$
$RHinge\_T = \lambda\, \theta : \mathbb{R} \bullet e^{[RHinge\_A]*(-\theta)} * Transform((\frac{\mathscr{L}}{4}, -(\frac{\mathscr{W}}{2} + \frac{\mathscr{R}}{4} + 0.5cm), \mathscr{R}, 0, \frac{\pi}{2}, \frac{\pi}{2}), (0, 0, \frac{3\mathscr{R}}{4} + \frac{\mathscr{H}}{2}, 0, 0, 0))$
$RHinge\_AdT = \lambda\, \theta : \mathbb{R} \bullet [Ad(RHinge\_T(\theta))]$

*SRangerState*

$timer : \mathbb{R}$
$LHinge\_tau : \mathbb{R};\ LHinge\_pV : \mathbb{R}^6;\ LHinge\_pA : \mathbb{R}^6$
$LHinge\_LMotor\_das : \mathbb{R}$
$RHinge\_tau : \mathbb{R};\ RHinge\_pV : \mathbb{R}^6;\ RHinge\_pA : \mathbb{R}^6$
$RHinge\_RMotor\_das : \mathbb{R}$
$IR\_voltage : \mathbb{R}$
**visible** $LHinge\_F : \mathbb{R}^6;\ LHinge\_fV : \mathbb{R}^6$
**visible** $LHinge\_LMotor\_T : real;\ LHinge\_fA : \mathbb{R}^6$
**visible** $RHinge\_F : \mathbb{R}^6;\ RHinge\_fV : \mathbb{R}^6$
**visible** $RHinge\_RMotor\_T : real;\ RHinge\_fA : \mathbb{R}^6$
**visible** $IR\_distance : \mathbb{R}$

**state** *SRangerState*

**SRangerLocal**

$$
\begin{array}{l}
LHinge\_theta : \mathbb{R};\ LHinge\_v : \mathbb{R};\ LHinge\_a : \mathbb{R} \\
RHinge\_theta : \mathbb{R};\ RHinge\_v : \mathbb{R};\ RHinge\_a : \mathbb{R} \\
LHinge\_LMotor\_Tm : \mathbb{R};\ LHinge\_LMotor\_Vemf : \mathbb{R};\ LHinge\_LMotor\_Tf : \mathbb{R} \\
LHinge\_LMotor\_V : \mathbb{R};\ LHinge\_LMotor\_i : \mathbb{R} \\
LHinge\_LMotor\_theta : \mathbb{R};\ LHinge\_LMotor\_av : \mathbb{R} \\
LHinge\_LMotor\_e : \mathbb{R} \\
RHinge\_RMotor\_Tm : \mathbb{R};\ RHinge\_RMotor\_Vemf : \mathbb{R};\ RHinge\_RMotor\_Tf : \mathbb{R} \\
RHinge\_RMotor\_V : \mathbb{R};\ RHinge\_RMotor\_i : \mathbb{R} \\
RHinge\_RMotor\_theta : \mathbb{R};\ RHinge\_RMotor\_av : \mathbb{R} \\
RHinge\_RMotor\_e : \mathbb{R}
\end{array}
$$

$$
\begin{array}{l}
SendToDModel \mathrel{\widehat=} ObstacleToDModel \\
ObstacleToDModel \mathrel{\widehat=} \ \textbf{if } IR\_voltage \geq 3.0 \\
\qquad \textbf{then } registerRead.obstacle.true \longrightarrow \textbf{Skip} \\
\qquad \textbf{else } registerRead.obstacle.false \longrightarrow \textbf{Skip}
\end{array}
$$

**MoveCallLocal**

$$
\begin{array}{l}
SRangerLocal \\
dsl : \mathbb{R} \\
dsr : \mathbb{R} \\
axisLength : \mathbb{R} \\
\hline
axisLength = \mathscr{W} + (\frac{2\mathscr{R}}{4} + 0.5cm)
\end{array}
$$

$$
MoveCall(lv : \mathbb{R};\ av : \mathbb{R}) \mathrel{\widehat=}
$$

$$
LHinge\_LMotor\_das, RHinge\_RMotor\_das \ : \left[ true, \left( \begin{array}{l} \exists\, MoveCallLocal \bullet \\ \quad LHinge\_LMotor\_das = dsl \\ \quad \land \\ \quad RHinge\_RMotor\_das = dsr \\ \quad \land \\ \quad lv = \frac{\mathscr{R}(dsl+dsr)}{2} \\ \quad \land \\ \quad av == \frac{\mathscr{R}(dsl-dsr)}{axisLength} \end{array} \right) \right]
$$

**StopCallLocal**

$$
SRangerLocal
$$

$$
StopCall \mathrel{\widehat=}
$$

$$
LHinge\_LMotor\_das, RHinge\_RMotor\_das \ : \left[ true, \left( \begin{array}{l} \exists\, StopCallLocal \bullet \\ \quad LHinge\_LMotor\_das = 0 \\ \quad \land \\ \quad RHinge\_RMotor\_das = 0 \end{array} \right) \right]
$$

$$
\begin{array}{l}
ReceiveFromDModel \mathrel{\widehat=} MoveCallFromDModel \ |||\ StopFromDModel \\
MoveCallFromDModel \mathrel{\widehat=} registerWrite.moveCall?lv?av \longrightarrow MoveCall(lv, av) \\
StopCallFromDModel \mathrel{\widehat=} registerWrite.stopCall?lv?av \longrightarrow StopCall
\end{array}
$$

**Evolve**

$\Lambda SRangerState$

$\exists SRangerLocal \bullet$

$$IR\_voltage = 4 * e^{-0.028784 * IR\_distance} \land$$

$$LHinge\_fV = LHinge\_AdT(LHinge\_theta) * LHinge\_pV + LHinge\_A * LHinge\_v \land$$

$$LHinge\_fA = \left( \begin{array}{l} LHinge\_AdT(LHinge\_theta) * LHinge\_pA + \\ ad(LHinge\_fV, LHinge\_A) * LHinge\_v * LHinge\_A * LHinge\_a \end{array} \right) \land$$

$$LHinge\_tau = LHinge\_F^T * LHinge\_A \land$$

$$\frac{\mathrm{d}LHinge\_theta}{\mathrm{d}t} = LHinge\_v \land \frac{\mathrm{d}LHinge\_v}{\mathrm{d}t} = LHinge\_a \land LHinge\_LMotor\_av = \frac{\mathrm{d}LHinge\_LMotor\_theta}{\mathrm{d}t} \land$$

$$LHinge\_LMotor\_Tm = LHinge\_LMotor\_Kt * LHinge\_LMotor\_i \land$$

$$LHinge\_LMotor\_Vemf = LHinge\_LMotor\_Ke * LHinge\_LMotor\_av \land$$

$$LHinge\_LMotor\_Tf = LHinge\_LMotor\_b * LHinge\_LMotor\_av \land$$

$$LHinge\_LMotor\_T = LHinge\_LMotor\_Tm - LHinge\_LMotor\_Tf \land$$

$$LHinge\_LMotor\_V = \left( \begin{array}{l} LHinge\_LMotor\_i * LHinge\_LMotor\_R + \\ LHinge\_LMotor\_L * \frac{\mathrm{d}LHinge\_LMotor\_i}{\mathrm{d}t} + LHinge\_LMotor\_Vemf \end{array} \right) \land$$

$$LHinge\_LMotor\_e = LHinge\_LMotor\_das - \frac{\mathrm{d}LHinge\_LMotor\_theta}{\mathrm{d}t} \land$$

$$LHinge\_LMotor\_V = \left( \begin{array}{l} LHinge\_LMotor\_Kp * LHinge\_LMotor\_e + \\ LHinge\_LMotor\_Ki * \int_0^t LHinge\_LMotor\_e \, d\tau + \\ LHinge\_LMotor\_Kd * LHinge\_LMotor\_av \end{array} \right) \land$$

$$LHinge\_LMotor\_T = LHinge\_tau \land$$

$$RHinge\_fV = RHinge\_AdT(RHinge\_theta) * RHinge\_pV + RHinge\_A * RHinge\_v \land$$

$$RHinge\_fA = \left( \begin{array}{l} RHinge\_AdT(RHinge\_theta) * RHinge\_pA + \\ ad(RHinge\_fV, RHinge\_A) * RHinge\_v * RHinge\_A * RHinge\_a \end{array} \right) \land$$

$$RHinge\_tau = RHinge\_F^T * RHinge\_A \land$$

$$\frac{\mathrm{d}RHinge\_theta}{\mathrm{d}t} = RHinge\_v \land \frac{\mathrm{d}RHinge\_v}{\mathrm{d}t} = RHinge\_a \land RHinge\_RMotor\_av = \frac{\mathrm{d}RHinge\_RMotor\_theta}{\mathrm{d}t} \land$$

$$RHinge\_RMotor\_Tm = RHinge\_RMotor\_Kt * RHinge\_RMotor\_i \land$$

$$RHinge\_RMotor\_Vemf = RHinge\_RMotor\_Ke * RHinge\_RMotor\_av \land$$

$$RHinge\_RMotor\_Tf = RHinge\_RMotor\_b * RHinge\_RMotor\_av \land$$

$$RHinge\_RMotor\_T = RHinge\_RMotor\_Tm - RHinge\_RMotor\_Tf \land$$

$$RHinge\_RMotor\_V = \left( \begin{array}{l} RHinge\_RMotor\_i * RHinge\_RMotor\_R + \\ RHinge\_RMotor\_L * \frac{\mathrm{d}RHinge\_RMotor\_i}{\mathrm{d}t} + RHinge\_RMotor\_Vemf \end{array} \right) \land$$

$$RHinge\_RMotor\_e = RHinge\_RMotor\_das - \frac{\mathrm{d}RHinge\_RMotor\_theta}{\mathrm{d}t} \land$$

$$RHinge\_RMotor\_V = \left( \begin{array}{l} RHinge\_RMotor\_Kp * RHinge\_RMotor\_e + \\ RHinge\_RMotor\_Ki * \int_0^t RHinge\_RMotor\_e \, d\tau + \\ RHinge\_RMotor\_Kd * RHinge\_RMotor\_av \end{array} \right) \land$$

$$RHinge\_RMotor\_T = LHinge\_tau \land$$

$$\frac{\mathrm{d}timer}{\mathrm{d}t} = 1$$

$\bullet$

$Init;$

$\mu X \bullet SendToDModel;\ ReceiveFromDModel \vartriangle \mathbf{Wait}(cycle);\ timer := 0;\ Evolve \vartriangle (timer \geq cycle \times tscale);\ X$

**end**

**process** $System \mathrel{\widehat=}$

$(SimCMovement \llbracket \{\!|\ registerRead, registerWrite, tock\ |\!\} \rrbracket SRanger) \setminus \{\!|\ registerRead, registerWrite, tock\ |\!\}$