```
Quit[];

SetDirectory[NotebookDirectory[]];
<< HurToolbox.m
```

```
HurToolbox for modeling and analysis of multibody systems 1.0.0.
HurToolbox mainly uses vector manipulation (vectors, dyadics).
Coordinates and matrix representation of the dyadics are also available.
Available methods: Newton-Euler
   Method, Euler-Lagrange Method, Hamiltonian Method, Kane's Method.
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```

```
HurInitialize[]

HurLoadData["data_dynamicsA_abs.m"]

HurDefineRF[a, b, c, d]
HurDefineGeneralizedCoordinates[q1[t], q2[t]]
HurDefineDCM[a, q1[t], {0, 0, 1}]
HurDefineDCM[b, q2[t], {0, 0, 1}]
HurDefineDCM[d, -gamma, {0, 0, 1}]

FOOTST = 0;
COMA = FOOTST + la a2; (*COM of stance leg*)
COMB = FOOTST + (la + lb) a2 - lb b2; (*COM of swing leg*)
COMC = FOOTST + (la + lb) a2; (*Hip*)
HIP = COMC;
FOOTSW = FOOTST + (la + lb) a2 - (la + lb) b2; (*Swing foot position*)

HurDefineCOMPos[a, COMA];
HurDefineCOMPos[b, COMB];
HurDefineCOMPos[c, COMC];

HurKinematics[]
```

```
HurGlobalCOMVel
HurGlobalCOMAcc
HurGlobalAngularVel
HurGlobalAngularAcc
```

$$\{0,\ -a1\ la\ q1'[t],\ -(la+lb)\ (b1\ Cos[q1[t]-q2[t]]+b2\ Sin[q1[t]-q2[t]])\ q1'[t]+b1\ lb\ q2'[t],\ -(la+lb)\ (c1\ Cos[q1[t]]+c2\ Sin[q1[t]])\ q1'[t],\ 0\}$$

$$\{0,\ -la\ (a2\ q1'[t]^2+a1\ q1''[t]),\ b2\ (-(la+lb)\ Cos[q1[t]-q2[t]]\ q1'[t]^2+lb\ q2'[t]^2-(la+lb)\ Sin[q1[t]-q2[t]]\ q1''[t])+b1\ ((la+lb)\ Sin[q1[t]-q2[t]]\ q1'[t]^2-(la+lb)\ Cos[q1[t]-q2[t]]\ q1''[t]+lb\ q2''[t]),\ -(la+lb)\ ((c2\ Cos[q1[t]]-c1\ Sin[q1[t]])\ q1'[t]^2+(c1\ Cos[q1[t]]+c2\ Sin[q1[t]])\ q1''[t]),\ 0\}$$

$$\{0,\ n3\ q1'[t],\ n3\ q2'[t],\ 0,\ 0\}$$

$$\{0,\ a3\ q1''[t],\ b3\ q2''[t],\ 0,\ 0\}$$

```
HurDefineMass[a, m];
HurDefineMass[b, m];
HurDefineMass[c, mh];
HurDefineInertia[a, {0, 0, 0, 0, 0, Iz}];
HurDefineInertia[b, {0, 0, 0, 0, 0, Iz}];

HurDefineVertical[n2];

Jaf = HurGetJacobian[FOOTST, a, n]
Jah = HurGetJacobian[HIP, a, n]
Jbh = HurGetJacobian[HIP, b, n]
```

$$\{\{0,0\},\{0,0\},\{0,0\},\{0,0\},\{0,0\},\{1,0\}\}$$

$$\{\{-(la+lb)\ Cos[q1[t]],0\},\{-(la+lb)\ Sin[q1[t]],0\},\{0,0\},\{0,0\},\{0,0\},\{1,0\}\}$$

$$\{\{-(la+lb)\ Cos[q1[t]],0\},\{-(la+lb)\ Sin[q1[t]],0\},\{0,0\},\{0,0\},\{0,0\},\{0,1\}\}$$

```
Transpose[Jaf].HurList2Column[{0, 0, 0, 0, 0, tau1}] +
  Transpose[Jah].HurList2Column[{0, 0, 0, 0, 0, -tau2}] +
  Transpose[Jbh].HurList2Column[{0, 0, 0, 0, 0, tau2}] // MatrixForm
```

$$\begin{pmatrix} tau1-tau2 \\ tau2 \end{pmatrix}$$

```
HurDefineNonConservativeForces[tau1 - tau2, tau2]
```

$$\{tau1-tau2,\ tau2\}$$

```
HurELEquation[]
```

$$\{-tau1+tau2-2\ g\ la\ m\ Sin[q1[t]]-g\ lb\ m\ Sin[q1[t]]-g\ la\ mh\ Sin[q1[t]]-g\ lb\ mh\ Sin[q1[t]]-lb\ (la+lb)\ m\ Sin[q1[t]-q2[t]]\ q2'[t]^2+(Iz+2\ la\ lb\ (m+mh)+lb^2\ (m+mh)+la^2\ (2\ m+mh))\ q1''[t]-la\ lb\ m\ Cos[q1[t]-q2[t]]\ q2''[t]-lb^2\ m\ Cos[q1[t]-q2[t]]\ q2''[t],\ -tau2+g\ lb\ m\ Sin[q2[t]]+lb\ (la+lb)\ m\ Sin[q1[t]-q2[t]]\ q1'[t]^2-lb\ (la+lb)\ m\ Cos[q1[t]-q2[t]]\ q1''[t]+Iz\ q2''[t]+lb^2\ m\ q2''[t]\}$$

HurGlobalMMatrix // MatrixForm

$$\begin{pmatrix} Iz + 2\,la\,lb\,(m + mh) + lb^2\,(m + mh) + la^2\,(2\,m + mh) & -lb\,(la + lb)\,m\,\text{Cos}[q1[t] - q2[t]] \\ -lb\,(la + lb)\,m\,\text{Cos}[q1[t] - q2[t]] & Iz + lb^2\,m \end{pmatrix}$$

HurGlobalCMatrix // MatrixForm

$$\begin{pmatrix} 0 & -lb\,(la + lb)\,m\,\text{Sin}[q1[t] - q2[t]]\,q2'[t] \\ lb\,(la + lb)\,m\,\text{Sin}[q1[t] - q2[t]]\,q1'[t] & 0 \end{pmatrix}$$

HurGlobalGVector // MatrixForm

$$\begin{pmatrix} -g\,(lb\,(m + mh) + la\,(2\,m + mh))\,\text{Sin}[q1[t]] \\ g\,lb\,m\,\text{Sin}[q2[t]] \end{pmatrix}$$

invsol = Flatten[HurELInverse[]]

$$\begin{aligned}
&\{q1''[t] \to -\Big(\big(lb\,(la + lb)\,m\,\text{Cos}[q1[t] - q2[t]] \\
&\qquad \big(-tau2 + g\,lb\,m\,\text{Sin}[q2[t]] + lb\,(la + lb)\,m\,\text{Sin}[q1[t] - q2[t]]\,q1'[t]^2\big) + \\
&\qquad \big(Iz + lb^2\,m\big)\,\big(-tau1 + tau2 - g\,(lb\,(m + mh) + la\,(2\,m + mh))\,\text{Sin}[q1[t]] - \\
&\qquad\quad lb\,(la + lb)\,m\,\text{Sin}[q1[t] - q2[t]]\,q2'[t]^2\big)\big) \Big/ \\
&\quad \Big(\big(Iz + lb^2\,m\big)\,\big(Iz + 2\,la\,lb\,(m + mh) + lb^2\,(m + mh) + la^2\,(2\,m + mh)\big) - \\
&\qquad lb^2\,(la + lb)^2\,m^2\,\text{Cos}[q1[t] - q2[t]]^2\Big)\Big), \\
&q2''[t] \to \Big(2\,Iz\,tau2 + 4\,la^2\,m\,tau2 + 4\,la\,lb\,m\,tau2 + 2\,lb^2\,m\,tau2 + 2\,la^2\,mh\,tau2 + \\
&\qquad 4\,la\,lb\,mh\,tau2 + 2\,lb^2\,mh\,tau2 + 2\,la\,lb\,m\,tau1\,\text{Cos}[q1[t] - q2[t]] + \\
&\qquad 2\,lb^2\,m\,tau1\,\text{Cos}[q1[t] - q2[t]] - 2\,la\,lb\,m\,tau2\,\text{Cos}[q1[t] - q2[t]] - \\
&\qquad 2\,lb^2\,m\,tau2\,\text{Cos}[q1[t] - q2[t]] + 2\,g\,la^2\,lb\,m^2\,\text{Sin}[2\,q1[t] - q2[t]] + \\
&\qquad 3\,g\,la\,lb^2\,m^2\,\text{Sin}[2\,q1[t] - q2[t]] + g\,lb^3\,m^2\,\text{Sin}[2\,q1[t] - q2[t]] + \\
&\qquad g\,la^2\,lb\,m\,mh\,\text{Sin}[2\,q1[t] - q2[t]] + 2\,g\,la\,lb^2\,m\,mh\,\text{Sin}[2\,q1[t] - q2[t]] + \\
&\qquad g\,lb^3\,m\,mh\,\text{Sin}[2\,q1[t] - q2[t]] - 2\,g\,Iz\,lb\,m\,\text{Sin}[q2[t]] - \\
&\qquad 2\,g\,la^2\,lb\,m^2\,\text{Sin}[q2[t]] - g\,la\,lb^2\,m^2\,\text{Sin}[q2[t]] - g\,lb^3\,m^2\,\text{Sin}[q2[t]] - \\
&\qquad g\,la^2\,lb\,m\,mh\,\text{Sin}[q2[t]] - 2\,g\,la\,lb^2\,m\,mh\,\text{Sin}[q2[t]] - g\,lb^3\,m\,mh\,\text{Sin}[q2[t]] - \\
&\qquad 2\,lb\,(la + lb)\,m\,\big(Iz + 2\,la\,lb\,(m + mh) + lb^2\,(m + mh) + la^2\,(2\,m + mh)\big) \\
&\qquad\quad \text{Sin}[q1[t] - q2[t]]\,q1'[t]^2 + lb^2\,(la + lb)^2\,m^2\,\text{Sin}\big[2\,(q1[t] - q2[t])\big]\,q2'[t]^2\Big) \Big/ \\
&\quad \Big(2\,Iz^2 + 2\,Iz\,\big(2\,la\,lb\,(m + mh) + la^2\,(2\,m + mh) + lb^2\,(2\,m + mh)\big) + \\
&\qquad lb^2\,m\,\big(2\,la\,lb\,(m + 2\,mh) + lb^2\,(m + 2\,mh) + la^2\,(3\,m + 2\,mh)\big) - \\
&\qquad lb^2\,(la + lb)^2\,m^2\,\text{Cos}\big[2\,(q1[t] - q2[t])\big]\Big)\Big)\}
\end{aligned}$$

```
q1dd = q1''[t] /. invsol
HurToJulia[q1dd]
```

$$-\Big(\big(\mathrm{lb}\,(\mathrm{la}+\mathrm{lb})\,\mathrm{m}\,\mathrm{Cos}[\mathrm{q1}[t]-\mathrm{q2}[t]]\,\big(-\mathrm{tau2}+\mathrm{g}\,\mathrm{lb}\,\mathrm{m}\,\mathrm{Sin}[\mathrm{q2}[t]]+\mathrm{lb}\,(\mathrm{la}+\mathrm{lb})\,\mathrm{m}\,\mathrm{Sin}[\mathrm{q1}[t]-\mathrm{q2}[t]]\,\mathrm{q1}'[t]^2\big)+(\mathrm{Iz}+\mathrm{lb}^2\,\mathrm{m})\,\big(-\mathrm{tau1}+\mathrm{tau2}-\mathrm{g}\,(\mathrm{lb}\,(\mathrm{m}+\mathrm{mh})+\mathrm{la}\,(2\,\mathrm{m}+\mathrm{mh}))\,\mathrm{Sin}[\mathrm{q1}[t]]-\mathrm{lb}\,(\mathrm{la}+\mathrm{lb})\,\mathrm{m}\,\mathrm{Sin}[\mathrm{q1}[t]-\mathrm{q2}[t]]\,\mathrm{q2}'[t]^2\big)\big)\Big/\big((\mathrm{Iz}+\mathrm{lb}^2\,\mathrm{m})\,(\mathrm{Iz}+2\,\mathrm{la}\,\mathrm{lb}\,(\mathrm{m}+\mathrm{mh})+\mathrm{lb}^2\,(\mathrm{m}+\mathrm{mh})+\mathrm{la}^2\,(2\,\mathrm{m}+\mathrm{mh}))-\mathrm{lb}^2\,(\mathrm{la}+\mathrm{lb})^2\,\mathrm{m}^2\,\mathrm{Cos}[\mathrm{q1}[t]-\mathrm{q2}[t]]^2\big)\Big)$$

```
-1*(((Iz+(lb)^(2)*m)*(Iz+(2*la*lb*(m+mh)+((lb)^(2)*(m+mh)+(la)^(2)*(2*m+mh))))+-1*(lb
)^(2)*((la+lb))^(2)*(m)^(2)*(cos((q1+-1*q2)))^(2)))^(-1)*(lb*(la+lb)*m*cos((q1+-1*
q2))*(-1*tau2+(g*lb*m*sin(q2)+lb*(la+lb)*m*sin((q1+-1*q2))*(q1d)^(2)))+(Iz+(lb)^(2)
*m)*(-1*tau1+(tau2+(-1*g*(lb*(m+mh)+la*(2*m+mh))*sin(q1)+-1*lb*(la+lb)*m*sin((q1+-1
*q2))*(q2d)^(2)))))
```

```
q2dd = q2''[t] /. invsol
HurToJulia[q2dd]
```

$$\Big(2\,\mathrm{Iz}\,\mathrm{tau2}+4\,\mathrm{la}^2\,\mathrm{m}\,\mathrm{tau2}+4\,\mathrm{la}\,\mathrm{lb}\,\mathrm{m}\,\mathrm{tau2}+2\,\mathrm{lb}^2\,\mathrm{m}\,\mathrm{tau2}+2\,\mathrm{la}^2\,\mathrm{mh}\,\mathrm{tau2}+4\,\mathrm{la}\,\mathrm{lb}\,\mathrm{mh}\,\mathrm{tau2}+2\,\mathrm{lb}^2\,\mathrm{mh}\,\mathrm{tau2}+2\,\mathrm{la}\,\mathrm{lb}\,\mathrm{m}\,\mathrm{tau1}\,\mathrm{Cos}[\mathrm{q1}[t]-\mathrm{q2}[t]]+2\,\mathrm{lb}^2\,\mathrm{m}\,\mathrm{tau1}\,\mathrm{Cos}[\mathrm{q1}[t]-\mathrm{q2}[t]]-2\,\mathrm{la}\,\mathrm{lb}\,\mathrm{m}\,\mathrm{tau2}\,\mathrm{Cos}[\mathrm{q1}[t]-\mathrm{q2}[t]]-2\,\mathrm{lb}^2\,\mathrm{m}\,\mathrm{tau2}\,\mathrm{Cos}[\mathrm{q1}[t]-\mathrm{q2}[t]]+2\,\mathrm{g}\,\mathrm{la}^2\,\mathrm{lb}\,\mathrm{m}^2\,\mathrm{Sin}[2\,\mathrm{q1}[t]-\mathrm{q2}[t]]+3\,\mathrm{g}\,\mathrm{la}\,\mathrm{lb}^2\,\mathrm{m}^2\,\mathrm{Sin}[2\,\mathrm{q1}[t]-\mathrm{q2}[t]]+\mathrm{g}\,\mathrm{lb}^3\,\mathrm{m}^2\,\mathrm{Sin}[2\,\mathrm{q1}[t]-\mathrm{q2}[t]]+\mathrm{g}\,\mathrm{la}^2\,\mathrm{lb}\,\mathrm{m}\,\mathrm{mh}\,\mathrm{Sin}[2\,\mathrm{q1}[t]-\mathrm{q2}[t]]+2\,\mathrm{g}\,\mathrm{la}\,\mathrm{lb}^2\,\mathrm{m}\,\mathrm{mh}\,\mathrm{Sin}[2\,\mathrm{q1}[t]-\mathrm{q2}[t]]+\mathrm{g}\,\mathrm{lb}^3\,\mathrm{m}\,\mathrm{mh}\,\mathrm{Sin}[2\,\mathrm{q1}[t]-\mathrm{q2}[t]]-2\,\mathrm{g}\,\mathrm{Iz}\,\mathrm{lb}\,\mathrm{m}\,\mathrm{Sin}[\mathrm{q2}[t]]-2\,\mathrm{g}\,\mathrm{la}^2\,\mathrm{lb}\,\mathrm{m}^2\,\mathrm{Sin}[\mathrm{q2}[t]]-\mathrm{g}\,\mathrm{la}\,\mathrm{lb}^2\,\mathrm{m}^2\,\mathrm{Sin}[\mathrm{q2}[t]]-\mathrm{g}\,\mathrm{lb}^3\,\mathrm{m}^2\,\mathrm{Sin}[\mathrm{q2}[t]]-\mathrm{g}\,\mathrm{la}^2\,\mathrm{lb}\,\mathrm{m}\,\mathrm{mh}\,\mathrm{Sin}[\mathrm{q2}[t]]-2\,\mathrm{g}\,\mathrm{la}\,\mathrm{lb}^2\,\mathrm{m}\,\mathrm{mh}\,\mathrm{Sin}[\mathrm{q2}[t]]-\mathrm{g}\,\mathrm{lb}^3\,\mathrm{m}\,\mathrm{mh}\,\mathrm{Sin}[\mathrm{q2}[t]]-2\,\mathrm{lb}\,(\mathrm{la}+\mathrm{lb})\,\mathrm{m}\,(\mathrm{Iz}+2\,\mathrm{la}\,\mathrm{lb}\,(\mathrm{m}+\mathrm{mh})+\mathrm{lb}^2\,(\mathrm{m}+\mathrm{mh})+\mathrm{la}^2\,(2\,\mathrm{m}+\mathrm{mh}))\,\mathrm{Sin}[\mathrm{q1}[t]-\mathrm{q2}[t]]\,\mathrm{q1}'[t]^2+\mathrm{lb}^2\,(\mathrm{la}+\mathrm{lb})^2\,\mathrm{m}^2\,\mathrm{Sin}[2\,(\mathrm{q1}[t]-\mathrm{q2}[t])]\,\mathrm{q2}'[t]^2\Big)\Big/\Big(2\,\mathrm{Iz}^2+2\,\mathrm{Iz}\,(2\,\mathrm{la}\,\mathrm{lb}\,(\mathrm{m}+\mathrm{mh})+\mathrm{la}^2\,(2\,\mathrm{m}+\mathrm{mh})+\mathrm{lb}^2\,(2\,\mathrm{m}+\mathrm{mh}))+\mathrm{lb}^2\,\mathrm{m}\,(2\,\mathrm{la}\,\mathrm{lb}\,(\mathrm{m}+2\,\mathrm{mh})+\mathrm{lb}^2\,(\mathrm{m}+2\,\mathrm{mh})+\mathrm{la}^2\,(3\,\mathrm{m}+2\,\mathrm{mh}))-\mathrm{lb}^2\,(\mathrm{la}+\mathrm{lb})^2\,\mathrm{m}^2\,\mathrm{Cos}[2\,(\mathrm{q1}[t]-\mathrm{q2}[t])]\Big)$$

```
((2*(Iz)^(2)+(2*Iz*(2*la*lb*(m+mh)+((la)^(2)*(2*m+mh)+(lb)^(2)*(2*m+mh)))+((lb)^(2)*m
*(2*la*lb*(m+2*mh)+((lb)^(2)*(m+2*mh)+(la)^(2)*(3*m+2*mh)))+-1*(lb)^(2)*((la+lb))^(
2)*(m)^(2)*cos(2*(q1+-1*q2))))))^(-1)*(2*Iz*tau2+(4*(la)^(2)*m*tau2+(4*la*lb*m*tau2
+(2*(lb)^(2)*m*tau2+(2*(la)^(2)*mh*tau2+(4*la*lb*mh*tau2+(2*(lb)^(2)*mh*tau2+(2*la*
lb*m*tau1*cos((q1+-1*q2))+(2*(lb)^(2)*m*tau1*cos((q1+-1*q2))+(-2*la*lb*m*tau2*cos((
q1+-1*q2))+(-2*(lb)^(2)*m*tau2*cos((q1+-1*q2))+(2*g*(la)^(2)*lb*(m)^(2)*sin((2*q1+-
1*q2))+(3*g*la*(lb)^(2)*(m)^(2)*sin((2*q1+-1*q2))+(g*(lb)^(3)*(m)^(2)*sin((2*q1+-1*
q2))+(g*(la)^(2)*lb*m*mh*sin((2*q1+-1*q2))+(2*g*la*(lb)^(2)*m*mh*sin((2*q1+-1*q2))+
(g*(lb)^(3)*m*mh*sin((2*q1+-1*q2))+(-2*g*Iz*lb*m*sin(q2)+(-2*g*(la)^(2)*lb*(m)^(2)*
sin(q2)+(-1*g*la*(lb)^(2)*(m)^(2)*sin(q2)+(-1*g*(lb)^(3)*(m)^(2)*sin(q2)+(-1*g*(la)
^(2)*lb*m*mh*sin(q2)+(-2*g*la*(lb)^(2)*m*mh*sin(q2)+(-1*g*(lb)^(3)*m*mh*sin(q2)+(-2
*lb*(la+lb)*m*(Iz+(2*la*lb*(m+mh)+((lb)^(2)*(m+mh)+(la)^(2)*(2*m+mh))))*sin((q1+-1*
q2))*(q1d)^(2)+(lb)^(2)*((la+lb))^(2)*(m)^(2)*sin(2*(q1+-1*q2))*(q2d)^(2))))))))))
)))))))))))))))
```

```
JacQ1dd = Grad[q1dd, {q1[t], q2[t], q1'[t], q2'[t]}] // Simplify
JacQ2dd = Grad[q2dd, {q1[t], q2[t], q1'[t], q2'[t]}] // Simplify
```

$$\left\{\left(-\left(\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\left(\text{Iz}+2\,\text{la}\,\text{lb}\left(\text{m}+\text{mh}\right)+\text{lb}^2\left(\text{m}+\text{mh}\right)+\text{la}^2\left(2\,\text{m}+\text{mh}\right)\right)-\right.\right.\right.$$
$$\left.\left.\left.\text{lb}^2\left(\text{la}+\text{lb}\right)^2\text{m}^2\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]^2\right)\right.$$
$$\left(\text{lb}^2\left(\text{la}+\text{lb}\right)^2\text{m}^2\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]^2\text{q1}'\left[\text{t}\right]^2-\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\right.$$
$$\left(-\text{tau2}+\text{g}\,\text{lb}\,\text{m}\,\text{Sin}\left[\text{q2}\left[\text{t}\right]\right]+\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{q1}'\left[\text{t}\right]^2\right)+$$
$$\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\left(-\text{g}\left(\text{lb}\left(\text{m}+\text{mh}\right)+\text{la}\left(2\,\text{m}+\text{mh}\right)\right)\text{Cos}\left[\text{q1}\left[\text{t}\right]\right]-\right.$$
$$\left.\left.\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{q2}'\left[\text{t}\right]^2\right)\right)+$$
$$2\,\text{lb}^2\left(\text{la}+\text{lb}\right)^2\text{m}^2\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\left(\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\right.$$
$$\left(-\text{tau2}+\text{g}\,\text{lb}\,\text{m}\,\text{Sin}\left[\text{q2}\left[\text{t}\right]\right]+\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{q1}'\left[\text{t}\right]^2\right)+$$
$$\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\left(-\text{tau1}+\text{tau2}-\text{g}\left(\text{lb}\left(\text{m}+\text{mh}\right)+\text{la}\left(2\,\text{m}+\text{mh}\right)\right)\text{Sin}\left[\text{q1}\left[\text{t}\right]\right]-\right.$$
$$\left.\left.\left.\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{q2}'\left[\text{t}\right]^2\right)\right)\right)\Big/$$
$$\left(\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\left(\text{Iz}+2\,\text{la}\,\text{lb}\left(\text{m}+\text{mh}\right)+\text{lb}^2\left(\text{m}+\text{mh}\right)+\text{la}^2\left(2\,\text{m}+\text{mh}\right)\right)-\right.$$
$$\left.\text{lb}^2\left(\text{la}+\text{lb}\right)^2\text{m}^2\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]^2\right)^2,$$
$$\left(\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\left(-\left(\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\left(\text{Iz}+2\,\text{la}\,\text{lb}\left(\text{m}+\text{mh}\right)+\text{lb}^2\left(\text{m}+\text{mh}\right)+\text{la}^2\left(2\,\text{m}+\text{mh}\right)\right)-\text{lb}^2\left(\text{la}+\text{lb}\right)^2\right.\right.\right.$$
$$\left.\left.\left.\text{m}^2\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]^2\right)\left(\text{g}\,\text{lb}\,\text{m}\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-2\,\text{q2}\left[\text{t}\right]\right]-\text{tau2}\,\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]-\right.\right.$$
$$\left.\left.\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Cos}\left[2\left(\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right)\right]\text{q1}'\left[\text{t}\right]^2+\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{q2}'\left[\text{t}\right]^2\right)-$$
$$2\,\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\left(\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\right.$$
$$\left(-\text{tau2}+\text{g}\,\text{lb}\,\text{m}\,\text{Sin}\left[\text{q2}\left[\text{t}\right]\right]+\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{q1}'\left[\text{t}\right]^2\right)+$$
$$\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\left(-\text{tau1}+\text{tau2}-\text{g}\left(\text{lb}\left(\text{m}+\text{mh}\right)+\text{la}\left(2\,\text{m}+\text{mh}\right)\right)\text{Sin}\left[\text{q1}\left[\text{t}\right]\right]-\right.$$
$$\left.\left.\left.\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{q2}'\left[\text{t}\right]^2\right)\right)\right)\Big/$$
$$\left(\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\left(\text{Iz}+2\,\text{la}\,\text{lb}\left(\text{m}+\text{mh}\right)+\text{lb}^2\left(\text{m}+\text{mh}\right)+\text{la}^2\left(2\,\text{m}+\text{mh}\right)\right)-\right.$$
$$\left.\text{lb}^2\left(\text{la}+\text{lb}\right)^2\text{m}^2\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]^2\right)^2,$$
$$-\left(\left(2\,\text{lb}^2\left(\text{la}+\text{lb}\right)^2\text{m}^2\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{q1}'\left[\text{t}\right]\right)\Big/\right.$$
$$\left(\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\left(\text{Iz}+2\,\text{la}\,\text{lb}\left(\text{m}+\text{mh}\right)+\text{lb}^2\left(\text{m}+\text{mh}\right)+\text{la}^2\left(2\,\text{m}+\text{mh}\right)\right)-\right.$$
$$\left.\left.\text{lb}^2\left(\text{la}+\text{lb}\right)^2\text{m}^2\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]^2\right)\right),$$
$$\left(2\,\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{q2}'\left[\text{t}\right]\right)\Big/$$
$$\left(\left(\text{Iz}+\text{lb}^2\,\text{m}\right)\left(\text{Iz}+2\,\text{la}\,\text{lb}\left(\text{m}+\text{mh}\right)+\text{lb}^2\left(\text{m}+\text{mh}\right)+\text{la}^2\left(2\,\text{m}+\text{mh}\right)\right)-\right.$$
$$\left.\text{lb}^2\left(\text{la}+\text{lb}\right)^2\text{m}^2\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]^2\right)\Bigg\}$$

$$\left\{\left(2\,\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\right.\right.$$
$$\left(\left(2\,\text{Iz}^2+2\,\text{Iz}\left(2\,\text{la}\,\text{lb}\left(\text{m}+\text{mh}\right)+\text{la}^2\left(2\,\text{m}+\text{mh}\right)+\text{lb}^2\left(2\,\text{m}+\text{mh}\right)\right)+\text{lb}^2\,\text{m}\left(2\,\text{la}\,\text{lb}\left(\text{m}+2\,\text{mh}\right)+\right.\right.\right.$$
$$\left.\left.\left.\text{lb}^2\left(\text{m}+2\,\text{mh}\right)+\text{la}^2\left(3\,\text{m}+2\,\text{mh}\right)\right)-\text{lb}^2\left(\text{la}+\text{lb}\right)^2\text{m}^2\,\text{Cos}\left[2\left(\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right)\right]\right)\right.$$
$$\left(2\,\text{g}\,\text{la}\,\text{m}\,\text{Cos}\left[2\,\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+\text{g}\,\text{lb}\,\text{m}\,\text{Cos}\left[2\,\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+\text{g}\,\text{la}\,\text{mh}\,\text{Cos}\left[2\,\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+\right.$$
$$\text{g}\,\text{lb}\,\text{mh}\,\text{Cos}\left[2\,\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]-\text{tau1}\,\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+\text{tau2}\,\text{Sin}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]-$$
$$\left(\text{Iz}+2\,\text{la}\,\text{lb}\left(\text{m}+\text{mh}\right)+\text{lb}^2\left(\text{m}+\text{mh}\right)+\text{la}^2\left(2\,\text{m}+\text{mh}\right)\right)\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]\text{q1}'\left[\text{t}\right]^2+$$
$$\left.\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Cos}\left[2\left(\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right)\right]\text{q2}'\left[\text{t}\right]^2\right)-$$
$$\text{lb}\left(\text{la}+\text{lb}\right)\text{m}\,\text{Sin}\left[2\left(\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right)\right]\left(2\,\text{Iz}\,\text{tau2}+4\,\text{la}^2\,\text{m}\,\text{tau2}+4\,\text{la}\,\text{lb}\,\text{m}\,\text{tau2}+2\,\text{lb}^2\,\text{m}\,\text{tau2}+\right.$$
$$2\,\text{la}^2\,\text{mh}\,\text{tau2}+4\,\text{la}\,\text{lb}\,\text{mh}\,\text{tau2}+2\,\text{lb}^2\,\text{mh}\,\text{tau2}+2\,\text{la}\,\text{lb}\,\text{m}\,\text{tau1}\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+$$
$$2\,\text{lb}^2\,\text{m}\,\text{tau1}\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]-2\,\text{la}\,\text{lb}\,\text{m}\,\text{tau2}\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]-$$
$$2\,\text{lb}^2\,\text{m}\,\text{tau2}\,\text{Cos}\left[\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+2\,\text{g}\,\text{la}^2\,\text{lb}\,\text{m}^2\,\text{Sin}\left[2\,\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+$$
$$3\,\text{g}\,\text{la}\,\text{lb}^2\,\text{m}^2\,\text{Sin}\left[2\,\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+\text{g}\,\text{lb}^3\,\text{m}^2\,\text{Sin}\left[2\,\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+$$
$$\text{g}\,\text{la}^2\,\text{lb}\,\text{m}\,\text{mh}\,\text{Sin}\left[2\,\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+2\,\text{g}\,\text{la}\,\text{lb}^2\,\text{m}\,\text{mh}\,\text{Sin}\left[2\,\text{q1}\left[\text{t}\right]-\text{q2}\left[\text{t}\right]\right]+$$

$$
\begin{aligned}
&g\,lb^3\,m\,mh\,\text{Sin}[2\,q1[t]-q2[t]]-2\,g\,Iz\,lb\,m\,\text{Sin}[q2[t]]-\\
&2\,g\,la^2\,lb\,m^2\,\text{Sin}[q2[t]]-g\,la\,lb^2\,m^2\,\text{Sin}[q2[t]]-g\,lb^3\,m^2\,\text{Sin}[q2[t]]-\\
&g\,la^2\,lb\,m\,mh\,\text{Sin}[q2[t]]-2\,g\,la\,lb^2\,m\,mh\,\text{Sin}[q2[t]]-g\,lb^3\,m\,mh\,\text{Sin}[q2[t]]-\\
&2\,lb\,(la+lb)\,m\,\left(Iz+2\,la\,lb\,(m+mh)+lb^2\,(m+mh)+la^2\,(2\,m+mh)\right)\\
&\quad\text{Sin}[q1[t]-q2[t]]\,q1'[t]^2+lb^2\,(la+lb)^2\,m^2\,\text{Sin}\left[2\,(q1[t]-q2[t])\right]\,q2'[t]^2\Big)\Big)\Big/\\
&\Big(2\,Iz^2+2\,Iz\,\left(2\,la\,lb\,(m+mh)+la^2\,(2\,m+mh)+lb^2\,(2\,m+mh)\right)+\\
&\quad lb^2\,m\,\left(2\,la\,lb\,(m+2\,mh)+lb^2\,(m+2\,mh)+la^2\,(3\,m+2\,mh)\right)-\\
&\quad lb^2\,(la+lb)^2\,m^2\,\text{Cos}\left[2\,(q1[t]-q2[t])\right]\Big)^2,\\
&\Big(lb\,m\,\Big(\left(2\,Iz^2+2\,Iz\,\left(2\,la\,lb\,(m+mh)+la^2\,(2\,m+mh)+lb^2\,(2\,m+mh)\right)+\right.\\
&\qquad lb^2\,m\,\left(2\,la\,lb\,(m+2\,mh)+lb^2\,(m+2\,mh)+la^2\,(3\,m+2\,mh)\right)-\\
&\qquad \left.lb^2\,(la+lb)^2\,m^2\,\text{Cos}\left[2\,(q1[t]-q2[t])\right]\right)\\
&\quad\Big(-2\,g\,la^2\,m\,\text{Cos}[2\,q1[t]-q2[t]]-3\,g\,la\,lb\,m\,\text{Cos}[2\,q1[t]-q2[t]]-\\
&\quad g\,lb^2\,m\,\text{Cos}[2\,q1[t]-q2[t]]-g\,la^2\,mh\,\text{Cos}[2\,q1[t]-q2[t]]-\\
&\quad 2\,g\,la\,lb\,mh\,\text{Cos}[2\,q1[t]-q2[t]]-g\,lb^2\,mh\,\text{Cos}[2\,q1[t]-q2[t]]-2\,g\,Iz\,\text{Cos}[q2[t]]-\\
&\quad 2\,g\,la^2\,m\,\text{Cos}[q2[t]]-g\,la\,lb\,m\,\text{Cos}[q2[t]]-g\,lb^2\,m\,\text{Cos}[q2[t]]-g\,la^2\,mh\,\text{Cos}[q2[t]]-\\
&\quad 2\,g\,la\,lb\,mh\,\text{Cos}[q2[t]]-g\,lb^2\,mh\,\text{Cos}[q2[t]]+2\,la\,tau1\,\text{Sin}[q1[t]-q2[t]]+\\
&\quad 2\,lb\,tau1\,\text{Sin}[q1[t]-q2[t]]-2\,la\,tau2\,\text{Sin}[q1[t]-q2[t]]-2\,lb\,tau2\\
&\qquad\text{Sin}[q1[t]-q2[t]]+2\,(la+lb)\,\left(Iz+2\,la\,lb\,(m+mh)+lb^2\,(m+mh)+la^2\,(2\,m+mh)\right)\\
&\qquad\text{Cos}[q1[t]-q2[t]]\,q1'[t]^2-2\,lb\,(la+lb)^2\,m\,\text{Cos}\left[2\,(q1[t]-q2[t])\right]\,q2'[t]^2\Big)+\\
&\quad 2\,lb\,(la+lb)^2\,m\,\text{Sin}\left[2\,(q1[t]-q2[t])\right]\,\Big(2\,Iz\,tau2+4\,la^2\,m\,tau2+4\,la\,lb\,m\,tau2+\\
&\quad 2\,lb^2\,m\,tau2+2\,la^2\,mh\,tau2+4\,la\,lb\,mh\,tau2+2\,lb^2\,mh\,tau2+\\
&\quad 2\,la\,lb\,m\,tau1\,\text{Cos}[q1[t]-q2[t]]+2\,lb^2\,m\,tau1\,\text{Cos}[q1[t]-q2[t]]-\\
&\quad 2\,la\,lb\,m\,tau2\,\text{Cos}[q1[t]-q2[t]]-2\,lb^2\,m\,tau2\,\text{Cos}[q1[t]-q2[t]]+\\
&\quad 2\,g\,la^2\,lb\,m^2\,\text{Sin}[2\,q1[t]-q2[t]]+3\,g\,la\,lb^2\,m^2\,\text{Sin}[2\,q1[t]-q2[t]]+\\
&\quad g\,lb^3\,m^2\,\text{Sin}[2\,q1[t]-q2[t]]+g\,la^2\,lb\,m\,mh\,\text{Sin}[2\,q1[t]-q2[t]]+2\,g\,la\,lb^2\,m\,mh\\
&\qquad\text{Sin}[2\,q1[t]-q2[t]]+g\,lb^3\,m\,mh\,\text{Sin}[2\,q1[t]-q2[t]]-2\,g\,Iz\,lb\,m\,\text{Sin}[q2[t]]-\\
&\quad 2\,g\,la^2\,lb\,m^2\,\text{Sin}[q2[t]]-g\,la\,lb^2\,m^2\,\text{Sin}[q2[t]]-g\,lb^3\,m^2\,\text{Sin}[q2[t]]-\\
&\quad g\,la^2\,lb\,m\,mh\,\text{Sin}[q2[t]]-2\,g\,la\,lb^2\,m\,mh\,\text{Sin}[q2[t]]-g\,lb^3\,m\,mh\,\text{Sin}[q2[t]]-\\
&\quad 2\,lb\,(la+lb)\,m\,\left(Iz+2\,la\,lb\,(m+mh)+lb^2\,(m+mh)+la^2\,(2\,m+mh)\right)\\
&\qquad\text{Sin}[q1[t]-q2[t]]\,q1'[t]^2+lb^2\,(la+lb)^2\,m^2\,\text{Sin}\left[2\,(q1[t]-q2[t])\right]\,q2'[t]^2\Big)\Big)\Big/\\
&\Big(2\,Iz^2+2\,Iz\,\left(2\,la\,lb\,(m+mh)+la^2\,(2\,m+mh)+lb^2\,(2\,m+mh)\right)+\\
&\quad lb^2\,m\,\left(2\,la\,lb\,(m+2\,mh)+lb^2\,(m+2\,mh)+la^2\,(3\,m+2\,mh)\right)-\\
&\quad lb^2\,(la+lb)^2\,m^2\,\text{Cos}\left[2\,(q1[t]-q2[t])\right]\Big)^2,\\
&-\Big(\left(4\,lb\,(la+lb)\,m\,\left(Iz+2\,la\,lb\,(m+mh)+lb^2\,(m+mh)+la^2\,(2\,m+mh)\right)\right.\\
&\qquad\text{Sin}[q1[t]-q2[t]]\,q1'[t]\Big)\Big/\\
&\quad\Big(2\,Iz^2+2\,Iz\,\left(2\,la\,lb\,(m+mh)+la^2\,(2\,m+mh)+lb^2\,(2\,m+mh)\right)+\\
&\qquad lb^2\,m\,\left(2\,la\,lb\,(m+2\,mh)+lb^2\,(m+2\,mh)+la^2\,(3\,m+2\,mh)\right)-\\
&\qquad \left.lb^2\,(la+lb)^2\,m^2\,\text{Cos}\left[2\,(q1[t]-q2[t])\right]\right)\Big),\\
&\Big(2\,lb^2\,(la+lb)^2\,m^2\,\text{Sin}\left[2\,(q1[t]-q2[t])\right]\,q2'[t]\Big)\Big/\\
&\Big(2\,Iz^2+\\
&\quad 2\,Iz\,\left(2\,la\,lb\,(m+mh)+la^2\,(2\,m+mh)+lb^2\,(2\,m+mh)\right)+\\
&\quad lb^2\,m\,\left(2\,la\,lb\,(m+2\,mh)+lb^2\,(m+2\,mh)+la^2\,(3\,m+2\,mh)\right)-
\end{aligned}
$$

$$lb^2 \left(la + lb\right)^2 m^2 \text{Cos}\left[2 \left(q1[t] - q2[t]\right)\right]\Big)\Big\}$$

HurSaveData["data_dynamicsA_abs.m", "invsol", "q1dd", "q2dd", "JacQ1dd", "JacQ2dd", "FOOTST", "COMA", "COMB", "COMC", "HIP", "FOOTSW"]

Julia expression for dynamic constraints

HurToJulia[q1dd]

```
-1*(((-1*(((Iz+((lb)^(2)*m+lb*(la+lb)*m*cos(q2))))^(2)+(Iz+(lb)^(2)*m)*(2*Iz+((la)^(2)*
  m+(((la+lb))^(2)*mh+(m*((lb+(la+lb)*cos(q2)))^(2)+((la+lb))^(2)*m*(sin(q2))^(2)))))
  ))^(-1)*(-1*(Iz+lb*m*(lb+(la+lb)*cos(q2))))*(-1*tau2+(-1*g*lb*m*sin((q1+q2))+lb*(la+
  lb)*m*sin(q2)*(q1d)^(2)))+-1*(Iz+(lb)^(2)*m)*(tau1+(2*g*la*m*sin(q1)+(g*lb*m*sin(q1)
  +(g*la*mh*sin(q1)+(g*lb*mh*sin(q1)+(g*lb*m*sin((q1+q2))+(2*lb*(la+lb)*m*sin(q2)*q1d*
  q2d+lb*(la+lb)*m*sin(q2)*(q2d)^(2)))))))))
```

HurToJulia[q2dd]

```
((2*(Iz)^(2)+(2*Iz*(2*la*lb*(m+mh)+((la)^(2)*(2*m+mh)+(lb)^(2)*(2*m+mh))))+((lb)^(2)*m
  *(2*la*lb*(m+2*mh)+((lb)^(2)*(m+2*mh)+(la)^(2)*(3*m+2*mh))))+-1*(lb)^(2)*((la+lb))^(
  2)*(m)^(2)*cos(2*q2))))^(-1)*(-2*Iz*tau1+(-2*(lb)^(2)*m*tau1+(4*Iz*tau2+(4*(la)^(2
  )*m*tau2+(4*la*lb*m*tau2+(4*(lb)^(2)*m*tau2+(2*(la)^(2)*mh*tau2+(4*la*lb*mh*tau2+(2*
  (lb)^(2)*mh*tau2+(-2*la*lb*m*tau1*cos(q2)+(-2*(lb)^(2)*m*tau1*cos(q2)+(4*la*lb*m*
  tau2*cos(q2)+(4*(lb)^(2)*m*tau2*cos(q2)+(-4*g*Iz*la*m*sin(q1)+(-2*g*Iz*lb*m*sin(q1)+
  (-3*g*la*(lb)^(2)*(m)^(2)*sin(q1)+(-1*g*(lb)^(3)*(m)^(2)*sin(q1)+(-2*g*Iz*la*mh*sin
  (q1)+(-2*g*Iz*lb*mh*sin(q1)+(-2*g*la*(lb)^(2)*m*mh*sin(q1)+(-2*g*(lb)^(3)*m*mh*sin(
  q1)+(2*g*Iz*lb*m*cos(q2)*sin(q1)+(-2*g*la*(lb)^(2)*(m)^(2)*cos(q2)*sin(q1)+(g*la*(lb
  )^(2)*(m)^(2)*(cos(q2))^(2)*sin(q1)+(g*(lb)^(3)*(m)^(2)*(cos(q2))^(2)*sin(q1)+(2*g*
  Iz*lb*m*cos(q1)*sin(q2)+(4*g*(la)^(2)*lb*(m)^(2)*cos(q1)*sin(q2)+(4*g*la*(lb)^(2)*(m
  )^(2)*cos(q1)*sin(q2)+(2*g*(lb)^(3)*(m)^(2)*cos(q1)*sin(q2)+(2*g*(la)^(2)*lb*m*mh*
  cos(q1)*sin(q2)+(4*g*la*(lb)^(2)*m*mh*cos(q1)*sin(q2)+(2*g*(lb)^(3)*m*mh*cos(q1)*sin
  (q2)+(-1*g*la*(lb)^(2)*(m)^(2)*sin(q1)*(sin(q2))^(2)+(-1*g*(lb)^(3)*(m)^(2)*sin(q1)
  *(sin(q2))^(2)+(g*la*(lb)^(2)*(m)^(2)*cos(q1)*sin(2*q2)+(g*(lb)^(3)*(m)^(2)*cos(q1)
  *sin(2*q2)+(-2*lb*(la+lb)*m*(2*Iz+(2*(la)^(2)*m+(2*la*lb*m+(2*(lb)^(2)*m+((la)^(2)*
  mh+(2*la*lb*mh+((lb)^(2)*mh+2*lb*(la+lb)*m*cos(q2))))))))*sin(q2)*(q1d)^(2)+(-4*lb*
  (la+lb)*m*(Iz+((lb)^(2)*m+lb*(la+lb)*m*cos(q2)))*sin(q2)*q1d*q2d+-2*lb*(la+lb)*m*(Iz
  +((lb)^(2)*m+lb*(la+lb)*m*cos(q2)))*sin(q2)*(q2d)^(2)))))))))))))))))))))))))))))))
  ))))))))))
```

HIP

HurUnifyTriadsCoord[HIP, n]

$$\text{a2}\left(\text{la} + \text{lb}\right)$$

$$\left\{-\left(\text{la} + \text{lb}\right) \text{Sin}[\text{q1}[\text{t}]],\ \left(\text{la} + \text{lb}\right) \text{Cos}[\text{q1}[\text{t}]],\ 0,\ \text{n}\right\}$$

```
HurUnifyTriadsCoord[FOOTSW, n] // MatrixForm
HurUnifyTriadsCoord[FOOTSW, d] // MatrixForm
```

$$\begin{pmatrix} (la + lb)\ (-\text{Sin}[q1[t]] + \text{Sin}[q2[t]]) \\ (la + lb)\ (\text{Cos}[q1[t]] - \text{Cos}[q2[t]]) \\ 0 \\ n \end{pmatrix}$$

$$\begin{pmatrix} (la + lb)\ (-\text{Sin}[\text{gamma} + q1[t]] + \text{Sin}[\text{gamma} + q2[t]]) \\ (la + lb)\ (\text{Cos}[\text{gamma} + q1[t]] - \text{Cos}[\text{gamma} + q2[t]]) \\ 0 \\ d \end{pmatrix}$$

```
HurToJulia[HurUnifyTriadsCoord[FOOTSW, n][[1]]]
```

```
(la+lb)*(-1*sin(q1)+sin(q2))
```

```
HurToJulia[HurUnifyTriadsCoord[FOOTSW, n][[2]]]
```

```
(la+lb)*(cos(q1)+-1*cos(q2))
```

```
HurToJulia[HurUnifyTriadsCoord[HIP, n][[1]]]
```

```
-1*(la+lb)*sin(q1)
```

```
HurToJulia[HurUnifyTriadsCoord[HIP, n][[2]]]
```

```
(la+lb)*cos(q1)
```

```
HurToJulia[HurUnifyTriadsCoord[FOOTSW, d][[1]]]
```

```
(la+lb)*(-1*sin((gamma+q1))+sin((gamma+q2)))
```

```
HurToJulia[HurUnifyTriadsCoord[FOOTSW, d][[2]]]
```

```
(la+lb)*(cos((gamma+q1))+-1*cos((gamma+q2)))
```

```
HurGlobalELEquation[[1]]
HurToJulia[%]
```

$$-\text{tau1} + \text{tau2} - 2\,g\,la\,m\,\text{Sin}[q1[t]] - g\,lb\,m\,\text{Sin}[q1[t]] - g\,la\,mh\,\text{Sin}[q1[t]] - g\,lb\,mh\,\text{Sin}[q1[t]] - lb\,(la + lb)\,m\,\text{Sin}[q1[t] - q2[t]]\,q2'[t]^2 + (Iz + 2\,la\,lb\,(m + mh) + lb^2\,(m + mh) + la^2\,(2\,m + mh))\,q1''[t] - la\,lb\,m\,\text{Cos}[q1[t] - q2[t]]\,q2''[t] - lb^2\,m\,\text{Cos}[q1[t] - q2[t]]\,q2''[t]$$

```
(-1*tau1+(tau2+(-2*g*la*m*sin(q1)+(-1*g*lb*m*sin(q1)+(-1*g*la*mh*sin(q1)+(-1*g*lb*mh*
  sin(q1)+(-1*lb*(la+lb)*m*sin((q1+-1*q2))*(q2d)^(2)+((Iz+(2*la*lb*(m+mh)+((lb)^(2)*(
  m+mh)+(la)^(2)*(2*m+mh))))*q1dd+(-1*la*lb*m*cos((q1+-1*q2))*q2dd+-1*(lb)^(2)*m*cos(
  (q1+-1*q2))*q2dd)))))))))
```

```
Clear[q1dd, q2dd]
```

```
HurGlobalELEquation[[2]]
HurToJulia[%]
```

$$-\text{tau2}+\text{g lb m Sin}[\text{q2}[\text{t}]]+\text{lb}\left(\text{la}+\text{lb}\right)\text{m Sin}[\text{q1}[\text{t}]-\text{q2}[\text{t}]]\,\text{q1}'[\text{t}]^2-\text{lb}\left(\text{la}+\text{lb}\right)\text{m Cos}[\text{q1}[\text{t}]-\text{q2}[\text{t}]]\,\text{q1}''[\text{t}]+\text{Iz q2}''[\text{t}]+\text{lb}^2\,\text{m q2}''[\text{t}]$$

```
(-1*tau2+(g*lb*m*sin(q2)+(lb*(la+lb)*m*sin((q1+-1*q2))*(q1d)^(2)+(-1*lb*(la+lb)*m*cos(
  (q1+-1*q2))*q1dd+(Iz*q2dd+(lb)^(2)*m*q2dd))))
```

```
HurGlobalELEquation // MatrixForm
```

$$\begin{pmatrix}-\text{tau1}-\text{g la m Sin}[\text{q1}[\text{t}]]-\text{g}\left(\text{la}+\text{lb}\right)\text{mh Sin}[\text{q1}[\text{t}]]+\text{g m}\left(-\left(\text{la}+\text{lb}\right)\text{Sin}[\text{q1}[\text{t}]]-\text{lb Sin}[\text{q1}[\text{t}]+\text{c}\end{pmatrix}$$

```
temp = HurGlobalELEquation[[2]] /.
  {q1[t] → q1, q2[t] → q2, q1'[t] → q1d, q2'[t] → q2d, q1''[t] → q1dd, q2''[t] → q2dd}
```

$$\text{Iz q2dd}+\text{lb}^2\,\text{m q2dd}-\text{tau2}+\text{q1dd}\left(\text{Iz}+\text{lb}^2\,\text{m}+\text{lb}\left(\text{la}+\text{lb}\right)\text{m Cos}[\text{q2}]\right)+\text{lb}\left(\text{la}+\text{lb}\right)\text{m q1d}^2\,\text{Sin}[\text{q2}]-\text{g lb m Sin}[\text{q1}+\text{q2}]$$

```
f[q1_, q2_, q1d_, q2d_, q1dd_, q2dd_] = temp
```

$$\text{Iz q2dd}+\text{lb}^2\,\text{m q2dd}-\text{tau2}+\text{q1dd}\left(\text{Iz}+\text{lb}^2\,\text{m}+\text{lb}\left(\text{la}+\text{lb}\right)\text{m Cos}[\text{q2}]\right)+\text{lb}\left(\text{la}+\text{lb}\right)\text{m q1d}^2\,\text{Sin}[\text{q2}]-\text{g lb m Sin}[\text{q1}+\text{q2}]$$

```
f[1, 1, 1, 1, 1, 1]
```

$$2\,\text{Iz}+2\,\text{lb}^2\,\text{m}-\text{tau2}+\text{lb}\left(\text{la}+\text{lb}\right)\text{m Cos}[1]+\text{lb}\left(\text{la}+\text{lb}\right)\text{m Sin}[1]-\text{g lb m Sin}[2]$$

```
g[q1_, q2_] := q1 + q2
```

```
g[1, 2]
```

```
3
```

```
HurGlobalMMatrix
HurToMatlab[%]
```

$$\left\{\left\{2\,\text{Iz}+\text{la}^2\,\text{m}+\left(\text{la}+\text{lb}\right)^2\text{mh}+\text{m}\left(\left(\text{lb}+\left(\text{la}+\text{lb}\right)\text{Cos}[\text{q2}[\text{t}]]\right)^2+\left(\text{la}+\text{lb}\right)^2\text{Sin}[\text{q2}[\text{t}]]^2\right),\ \text{Iz}+\text{lb m}\left(\text{lb}+\left(\text{la}+\text{lb}\right)\text{Cos}[\text{q2}[\text{t}]]\right)\right\},\ \left\{\text{Iz}+\text{lb}^2\,\text{m}+\text{lb}\left(\text{la}+\text{lb}\right)\text{m Cos}[\text{q2}[\text{t}]],\ \text{Iz}+\text{lb}^2\,\text{m}\right\}\right\}$$

```
[(2*Iz+((la)^(2)*m+(((la+lb))^(2)*mh+m*(((lb+(la+lb)*cos(q2)))^(2)+((la+lb))^(2)*(sin
  (q2))^(2)))));(Iz+lb*m*(lb+(la+lb)*cos(q2)));(Iz+((lb)^(2)*m+lb*(la+lb)*m*cos(q2)))
  ,(Iz+(lb)^(2)*m)]
```

```
HurGlobalMMatrix
HurToJulia[%]
```

$$\left\{\left\{\text{Iz}+2\,\text{la lb}\left(\text{m}+\text{mh}\right)+\text{lb}^2\left(\text{m}+\text{mh}\right)+\text{la}^2\left(2\,\text{m}+\text{mh}\right),\ -\text{lb}\left(\text{la}+\text{lb}\right)\text{m Cos}[\text{q1}[\text{t}]-\text{q2}[\text{t}]]\right\},\ \left\{-\text{lb}\left(\text{la}+\text{lb}\right)\text{m Cos}[\text{q1}[\text{t}]-\text{q2}[\text{t}]],\ \text{Iz}+\text{lb}^2\,\text{m}\right\}\right\}$$

```
[(Iz+(2*la*lb*(m+mh)+((lb)^(2)*(m+mh)+(la)^(2)*(2*m+mh))))
  -1*lb*(la+lb)*m*cos((q1+-1*q2));-1*lb*(la+lb)*m*cos((q1+-1*q2))  (Iz+(lb)^(2)*m)]
```

HurGlobalCMatrix

HurToJulia[%]

$$\left\{\left\{0, -lb\ \left(la + lb\right)\ m\ Sin[q1[t] - q2[t]]\ q2'[t]\right\}, \left\{lb\ \left(la + lb\right)\ m\ Sin[q1[t] - q2[t]]\ q1'[t], 0\right\}\right\}$$

```
[0 -1*lb*(la+lb)*m*sin((q1+-1*q2))*q2d;lb*(la+lb)*m*sin((q1+-1*q2))*q1d 0]
```

HurGlobalGVector

HurToJulia[HurList2Column[%]]

$$\left\{-g\ \left(lb\ \left(m + mh\right) + la\ \left(2\ m + mh\right)\right)\ Sin[q1[t]], g\ lb\ m\ Sin[q2[t]]\right\}$$

```
[-1*g*(lb*(m+mh)+la*(2*m+mh))*sin(q1);g*lb*m*sin(q2)]
```