```
Quit[];

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

```
D:\Pilwon\Dropbox\TAMU\Group\Project\Walker\five_link

HurToolbox for modeling and analysis of multibody systems 1.0.1.
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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Email questions, comments, or concerns to pilwonhur@tamu.edu.
```

```
HurInitialize[]

HurLoadData["data_imp_1.m"]

HurDefineRF[a, b, c, d, e]
HurDefineGeneralizedCoordinates[q1[t], q2[t], q3[t], q4[t], q5[t], q6[t], q7[t]]
HurDefineDCM[a, q1[t], {0, 0, 1}]
HurDefineDCM[b, q2[t], {0, 0, 1}]
HurDefineDCM[c, q3[t], {0, 0, 1}]
HurDefineDCM[d, q4[t], {0, 0, 1}]
HurDefineDCM[e, q5[t], {0, 0, 1}]

FootST = q6[t] n1 + q7[t] n2;
ShankSTCOM = FootST + lsa a2;
KneeST = FootST + (lsa + lsb) a2;
ThighSTCOM = KneeST + lta b2;
Hip = KneeST + (lta + ltb) b2;
TorsoCOM = Hip + lb / 2 c2;
ThighSWCOM = Hip - ltb d2;
KneeSW = Hip - (ltb + lta) d2;
ShankSWCOM = KneeSW - lsb e2;
FootSW = KneeSW - (lsb + lsa) e2;

HurDefineCOMPos[a, ShankSTCOM]
HurDefineCOMPos[b, ThighSTCOM]
HurDefineCOMPos[c, TorsoCOM]
HurDefineCOMPos[d, ThighSWCOM]
HurDefineCOMPos[e, ShankSWCOM]

HurKinematics[]
```

```
HurDefineMass[a, ms]
HurDefineMass[b, mt]
HurDefineMass[c, mb]
HurDefineMass[d, mt]
HurDefineMass[e, ms]
HurDefineInertia[a, {0, 0, 0, 0, 0, Is}]
HurDefineInertia[b, {0, 0, 0, 0, 0, It}]
HurDefineInertia[c, {0, 0, 0, 0, 0, Ib}]
HurDefineInertia[d, {0, 0, 0, 0, 0, It}]
HurDefineInertia[e, {0, 0, 0, 0, 0, Is}]
```

```
HurDefineVertical[n2]
```

```
Transpose[HurGetJacobian[FootST, a, n]].HurList2Column[{0, 0, 0, 0, 0, tau1}] +
 Transpose[HurGetJacobian[KneeST, a, n]].HurList2Column[{0, 0, 0, 0, 0, -tau2}] +
 Transpose[HurGetJacobian[KneeST, b, n]].HurList2Column[{0, 0, 0, 0, 0, tau2}] +
 Transpose[HurGetJacobian[Hip, b, n]].HurList2Column[{0, 0, 0, 0, 0, -tau3}] +
 Transpose[HurGetJacobian[Hip, c, n]].HurList2Column[{0, 0, 0, 0, 0, tau3}] +
 Transpose[HurGetJacobian[Hip, c, n]].HurList2Column[{0, 0, 0, 0, 0, -tau4}] +
 Transpose[HurGetJacobian[Hip, d, n]].HurList2Column[{0, 0, 0, 0, 0, tau4}] +
 Transpose[HurGetJacobian[KneeSW, d, n]].HurList2Column[{0, 0, 0, 0, 0, -tau5}] +
 Transpose[HurGetJacobian[KneeSW, e, n]].HurList2Column[{0, 0, 0, 0, 0, tau5}]
HurDefineNonConservativeForces[Flatten[%]]
```

```
{{tau1 - tau2}, {tau2 - tau3}, {tau3 - tau4}, {tau4 - tau5}, {tau5}, {0}, {0}}
```

```
{tau1 - tau2, tau2 - tau3, tau3 - tau4, tau4 - tau5, tau5, 0, 0}
```

```
HurELEquation[]
```

```
HurGlobalELEquation // MatrixForm
```

```
HurGlobalMMatrix // MatrixForm
```

```
HurGlobalCMatrix // MatrixForm
```

```
HurGlobalGVector // MatrixForm
```

```
HurSaveData["data_imp_1.m", "FootST", "ShankSTCOM", "KneeST", "ThighSTCOM",
 "Hip", "TorsoCOM", "ThighSWCOM", "KneeSW", "ShankSWCOM", "FootSW"]
```

```
dyn1 = HurGlobalELEquation[[1]]
HurToJulia[dyn1]
```

```
1/2*(-2*tau1+(2*tau2+(-2*g*lsa*mb*sin(q1)+(-2*g*lsb*mb*sin(q1)+(-4*g*lsa*ms*sin(q1)+(-
  2*g*lsb*ms*sin(q1)+(-4*g*lsa*mt*sin(q1)+(-4*g*lsb*mt*sin(q1)+(2*(lsa+lsb)*(ltb*(mb+(
  ms+mt))+lta*(mb+(ms+2*mt))))*sin((q1+-1*q2))*(q2d)^(2)+(lb*(lsa+lsb)*mb*sin((q1+-1*q3
  ))*(q3d)^(2)+(-2*lsa*lta*ms*sin((q1+-1*q4))*(q4d)^(2)+(-2*lsb*lta*ms*sin((q1+-1*q4))
  *(q4d)^(2)+(-2*lsa*ltb*ms*sin((q1+-1*q4))*(q4d)^(2)+(-2*lsb*ltb*ms*sin((q1+-1*q4))*(
  q4d)^(2)+(-2*lsa*ltb*mt*sin((q1+-1*q4))*(q4d)^(2)+(-2*lsb*ltb*mt*sin((q1+-1*q4))*(
  q4d)^(2)+(-2*lsa*lsb*ms*sin((q1+-1*q5))*(q5d)^(2)+(-2*(lsb)^(2)*ms*sin((q1+-1*q5))*
  (q5d)^(2)+(2*Is*q1dd+(2*(lsa)^(2)*mb*q1dd+(4*lsa*lsb*mb*q1dd+(2*(lsb)^(2)*mb*q1dd+(4
  *(lsa)^(2)*ms*q1dd+(4*lsa*lsb*ms*q1dd+(2*(lsb)^(2)*ms*q1dd+(4*(lsa)^(2)*mt*q1dd+(8*
  lsa*lsb*mt*q1dd+(4*(lsb)^(2)*mt*q1dd+(2*lsa*lta*mb*cos((q1+-1*q2))*q2dd+(2*lsb*lta*
  mb*cos((q1+-1*q2))*q2dd+(2*lsa*ltb*mb*cos((q1+-1*q2))*q2dd+(2*lsb*ltb*mb*cos((q1+-1*
  q2))*q2dd+(2*lsa*lta*ms*cos((q1+-1*q2))*q2dd+(2*lsb*lta*ms*cos((q1+-1*q2))*q2dd+(2*
  lsa*ltb*ms*cos((q1+-1*q2))*q2dd+(2*lsb*ltb*ms*cos((q1+-1*q2))*q2dd+(4*lsa*lta*mt*cos
  ((q1+-1*q2))*q2dd+(4*lsb*lta*mt*cos((q1+-1*q2))*q2dd+(2*lsa*ltb*mt*cos((q1+-1*q2))*
  q2dd+(2*lsb*ltb*mt*cos((q1+-1*q2))*q2dd+(lb*lsa*mb*cos((q1+-1*q3))*q3dd+(lb*lsb*mb*
  cos((q1+-1*q3))*q3dd+(-2*lsa*lta*ms*cos((q1+-1*q4))*q4dd+(-2*lsb*lta*ms*cos((q1+-1*
  q4))*q4dd+(-2*lsa*ltb*ms*cos((q1+-1*q4))*q4dd+(-2*lsb*ltb*ms*cos((q1+-1*q4))*q4dd+(-
  2*lsa*ltb*mt*cos((q1+-1*q4))*q4dd+(-2*lsb*ltb*mt*cos((q1+-1*q4))*q4dd+(-2*lsa*lsb*ms
  *cos((q1+-1*q5))*q5dd+(-2*(lsb)^(2)*ms*cos((q1+-1*q5))*q5dd+(-2*lsa*mb*cos(q1)*q6dd+
  (-2*lsb*mb*cos(q1)*q6dd+(-4*lsa*ms*cos(q1)*q6dd+(-2*lsb*ms*cos(q1)*q6dd+(-4*lsa*mt*
  cos(q1)*q6dd+(-4*lsb*mt*cos(q1)*q6dd+(-2*lsa*mb*sin(q1)*q7dd+(-2*lsb*mb*sin(q1)*q7dd
  +(-4*lsa*ms*sin(q1)*q7dd+(-2*lsb*ms*sin(q1)*q7dd+(-4*lsa*mt*sin(q1)*q7dd+-4*lsb*mt*
  sin(q1)*q7dd)))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))))
```

```
dyn2 = HurGlobalELEquation[[2]]
HurToJulia[dyn2]
```

```
1/2*(-2*tau2+(2*tau3+(-2*g*lta*mb*sin(q2)+(-2*g*ltb*mb*sin(q2)+(-2*g*lta*ms*sin(q2)+(-
  2*g*ltb*ms*sin(q2)+(-4*g*lta*mt*sin(q2)+(-2*g*ltb*mt*sin(q2)+(-2*(lsa+lsb)*(ltb*(mb+
  (ms+mt))+lta*(mb+(ms+2*mt)))*sin((q1+-1*q2))*(q1d)^(2)+(lb*(lta+ltb)*mb*sin((q2+-1*
  q3))*(q3d)^(2)+(-2*(lta)^(2)*ms*sin((q2+-1*q4))*(q4d)^(2)+(-4*lta*ltb*ms*sin((q2+-1
  *q4))*(q4d)^(2)+(-2*(ltb)^(2)*ms*sin((q2+-1*q4))*(q4d)^(2)+(-2*lta*ltb*mt*sin((q2+-
  1*q4))*(q4d)^(2)+(-2*(ltb)^(2)*mt*sin((q2+-1*q4))*(q4d)^(2)+(-2*lsb*lta*ms*sin((q2+
  -1*q5))*(q5d)^(2)+(-2*lsb*ltb*ms*sin((q2+-1*q5))*(q5d)^(2)+(2*lsa*lta*mb*cos((q1+-1*
  q2))*q1dd+(2*lsb*lta*mb*cos((q1+-1*q2))*q1dd+(2*lsa*ltb*mb*cos((q1+-1*q2))*q1dd+(2*
  lsb*ltb*mb*cos((q1+-1*q2))*q1dd+(2*lsa*lta*ms*cos((q1+-1*q2))*q1dd+(2*lsb*lta*ms*cos
  ((q1+-1*q2))*q1dd+(2*lsa*ltb*ms*cos((q1+-1*q2))*q1dd+(2*lsb*ltb*ms*cos((q1+-1*q2))*
  q1dd+(4*lsa*lta*mt*cos((q1+-1*q2))*q1dd+(4*lsb*lta*mt*cos((q1+-1*q2))*q1dd+(2*lsa*
  ltb*mt*cos((q1+-1*q2))*q1dd+(2*lsb*ltb*mt*cos((q1+-1*q2))*q1dd+(2*It*q2dd+(2*(lta)^(
  2)*mb*q2dd+(4*lta*ltb*mb*q2dd+(2*(ltb)^(2)*mb*q2dd+(2*(lta)^(2)*ms*q2dd+(4*lta*ltb*
  ms*q2dd+(2*(ltb)^(2)*ms*q2dd+(4*(lta)^(2)*mt*q2dd+(4*lta*ltb*mt*q2dd+(2*(ltb)^(2)*mt
  *q2dd+(lb*lta*mb*cos((q2+-1*q3))*q3dd+(lb*ltb*mb*cos((q2+-1*q3))*q3dd+(-2*(lta)^(2)*
  ms*cos((q2+-1*q4))*q4dd+(-4*lta*ltb*ms*cos((q2+-1*q4))*q4dd+(-2*(ltb)^(2)*ms*cos((q2
  +-1*q4))*q4dd+(-2*lta*ltb*mt*cos((q2+-1*q4))*q4dd+(-2*(ltb)^(2)*mt*cos((q2+-1*q4))*
  q4dd+(-2*lsb*lta*ms*cos((q2+-1*q5))*q5dd+(-2*lsb*ltb*ms*cos((q2+-1*q5))*q5dd+(-2*lta
  *mb*cos(q2)*q6dd+(-2*ltb*mb*cos(q2)*q6dd+(-2*lta*ms*cos(q2)*q6dd+(-2*ltb*ms*cos(q2)*
  q6dd+(-4*lta*mt*cos(q2)*q6dd+(-2*ltb*mt*cos(q2)*q6dd+(-2*lta*mb*sin(q2)*q7dd+(-2*ltb
  *mb*sin(q2)*q7dd+(-2*lta*ms*sin(q2)*q7dd+(-2*ltb*ms*sin(q2)*q7dd+(-4*lta*mt*sin(q2)*
  q7dd+-2*ltb*mt*sin(q2)*q7dd)))))))))))))))))))))))))))))))))))))))))))))))))))))
  )))))
```

```
dyn3 = HurGlobalELEquation[[3]]
HurToJulia[dyn3]
```

```
1/4*(-4*tau3+(4*tau4+(-2*g*lb*mb*sin(q3)+(-2*lb*(lsa+lsb)*mb*sin((q1+-1*q3))*(q1d)^(2)
  +(-2*lb*(lta+ltb)*mb*sin((q2+-1*q3))*(q2d)^(2)+(2*lb*lsa*mb*cos((q1+-1*q3))*q1dd+(2*
  lb*lsb*mb*cos((q1+-1*q3))*q1dd+(2*lb*lta*mb*cos((q2+-1*q3))*q2dd+(2*lb*ltb*mb*cos((
  q2+-1*q3))*q2dd+(4*Ib*q3dd+((lb)^(2)*mb*q3dd+(-2*lb*mb*cos(q3)*q6dd+-2*lb*mb*sin(q3)
  *q7dd))))))))))))
```

```
dyn4 = HurGlobalELEquation[[4]]
HurToJulia[dyn4]
```

```
(-1*tau4+(tau5+(g*lta*ms*sin(q4)+(g*ltb*ms*sin(q4)+(g*ltb*mt*sin(q4)+((lsa+lsb)*(lta*
  ms+ltb*(ms+mt))*sin((q1+-1*q4))*(q1d)^(2)+((lta+ltb)*(lta*ms+ltb*(ms+mt))*sin((q2+-1
  *q4))*(q2d)^(2)+(lsb*lta*ms*sin((q4+-1*q5))*(q5d)^(2)+(lsb*ltb*ms*sin((q4+-1*q5))*(
  q5d)^(2)+(-1*lsa*lta*ms*cos((q1+-1*q4))*q1dd+(-1*lsb*lta*ms*cos((q1+-1*q4))*q1dd+(-1
  *lsa*ltb*ms*cos((q1+-1*q4))*q1dd+(-1*lsb*ltb*ms*cos((q1+-1*q4))*q1dd+(-1*lsa*ltb*mt*
  cos((q1+-1*q4))*q1dd+(-1*lsb*ltb*mt*cos((q1+-1*q4))*q1dd+(-1*(lta)^(2)*ms*cos((q2+-1
  *q4))*q2dd+(-2*lta*ltb*ms*cos((q2+-1*q4))*q2dd+(-1*(ltb)^(2)*ms*cos((q2+-1*q4))*q2dd
  +(-1*lta*ltb*mt*cos((q2+-1*q4))*q2dd+(-1*(ltb)^(2)*mt*cos((q2+-1*q4))*q2dd+(It*q4dd+
  ((lta)^(2)*ms*q4dd+(2*lta*ltb*ms*q4dd+((ltb)^(2)*ms*q4dd+((ltb)^(2)*mt*q4dd+(lsb*lta
  *ms*cos((q4+-1*q5))*q5dd+(lsb*ltb*ms*cos((q4+-1*q5))*q5dd+(lta*ms*cos(q4)*q6dd+(ltb*
  ms*cos(q4)*q6dd+(ltb*mt*cos(q4)*q6dd+(lta*ms*sin(q4)*q7dd+(ltb*ms*sin(q4)*q7dd+ltb*mt
  *sin(q4)*q7dd))))))))))))))))))))))))))))))))
```

```
dyn5 = HurGlobalELEquation[[5]]
HurToJulia[dyn5]
```

```
(-1*tau5+(g*lsb*ms*sin(q5)+(lsb*(lsa+lsb)*ms*sin((q1+-1*q5))*(q1d)^(2)+(lsb*(lta+ltb)*
  ms*sin((q2+-1*q5))*(q2d)^(2)+(-1*lsb*lta*ms*sin((q4+-1*q5))*(q4d)^(2)+(-1*lsb*ltb*ms
  *sin((q4+-1*q5))*(q4d)^(2)+(-1*lsa*lsb*ms*cos((q1+-1*q5))*q1dd+(-1*(lsb)^(2)*ms*cos(
  (q1+-1*q5))*q1dd+(-1*lsb*lta*ms*cos((q2+-1*q5))*q2dd+(-1*lsb*ltb*ms*cos((q2+-1*q5))*
  q2dd+(lsb*lta*ms*cos((q4+-1*q5))*q4dd+(lsb*ltb*ms*cos((q4+-1*q5))*q4dd+(Is*q5dd+((
  lsb)^(2)*ms*q5dd+(lsb*ms*cos(q5)*q6dd+lsb*ms*sin(q5)*q7dd)))))))))))))))
```

```
HurUnifyTriadsCoord[FootSW, n] // MatrixForm
```

$$\begin{pmatrix} q6[t] - (lsa + lsb)\,\text{Sin}[q1[t]] - (lta + ltb)\,\text{Sin}[q2[t]] + (lta + ltb)\,\text{Sin}[q4[t]] + (lsa + lsb)\,\text{Sin} \\ (lsa + lsb)\,\text{Cos}[q1[t]] + (lta + ltb)\,\text{Cos}[q2[t]] - (lta + ltb)\,\text{Cos}[q4[t]] - (lsa + lsb)\,\text{Cos}[q5[t]] \\ 0 \\ n \end{pmatrix}$$

```
stepLength = HurUnifyTriadsCoord[FootSW, n][[1]] /. {q6[t] → 0, q7[t] → 0}
HurToJulia[stepLength]
```

$$-(lsa + lsb)\,\text{Sin}[q1[t]] - (lta + ltb)\,\text{Sin}[q2[t]] + (lta + ltb)\,\text{Sin}[q4[t]] + (lsa + lsb)\,\text{Sin}[q5[t]]$$

```
(-1*(lsa+lsb)*sin(q1)+(-1*(lta+ltb)*sin(q2)+((lta+ltb)*sin(q4)+(lsa+lsb)*sin(q5))))
```

```
stepHeight = HurUnifyTriadsCoord[FootSW, n][[2]] /. {q6[t] → 0, q7[t] → 0}
HurToJulia[stepHeight]
```

$$(lsa + lsb)\,\text{Cos}[q1[t]] + (lta + ltb)\,\text{Cos}[q2[t]] - (lta + ltb)\,\text{Cos}[q4[t]] - (lsa + lsb)\,\text{Cos}[q5[t]]$$

```
((lsa+lsb)*cos(q1)+((lta+ltb)*cos(q2)+(-1*(lta+ltb)*cos(q4)+-1*(lsa+lsb)*cos(q5))))
```

```
JacFootSW = HurGetJacobian[FootSW, e, n][[1 ;; 2, ;;]]
```

$$\{\{-(lsa + lsb)\,\text{Cos}[q1[t]], -(lta + ltb)\,\text{Cos}[q2[t]], 0, (lta + ltb)\,\text{Cos}[q4[t]], (lsa + lsb)\,\text{Cos}[q5[t]], 1, 0\}, \{-(lsa + lsb)\,\text{Sin}[q1[t]], -(lta + ltb)\,\text{Sin}[q2[t]], 0, (lta + ltb)\,\text{Sin}[q4[t]], (lsa + lsb)\,\text{Sin}[q5[t]], 0, 1\}\}$$

```
impDynConst1 = ArrayFlatten[{{HurGlobalMMatrix, -Transpose[JacFootSW]}}].
    HurList2Column[{q1dp, q2dp, q3dp, q4dp, q5dp, q6dp, q7dp, F1, F2}] - HurGlobalMMatrix.
    HurList2Column[{q1'[t], q2'[t], q3'[t], q4'[t], q5'[t], 0, 0}] // Simplify
```

```
impDynConst2 = JacFootSW.HurList2Column[{q1dp, q2dp, q3dp, q4dp, q5dp, q6dp, q7dp}]
```

$$\{\{q6dp - (lsa + lsb)\,q1dp\,\text{Cos}[q1[t]] - (lta + ltb)\,q2dp\,\text{Cos}[q2[t]] + (lta + ltb)\,q4dp\,\text{Cos}[q4[t]] + (lsa + lsb)\,q5dp\,\text{Cos}[q5[t]]\}, \{q7dp - (lsa + lsb)\,q1dp\,\text{Sin}[q1[t]] - (lta + ltb)\,q2dp\,\text{Sin}[q2[t]] + (lta + ltb)\,q4dp\,\text{Sin}[q4[t]] + (lsa + lsb)\,q5dp\,\text{Sin}[q5[t]]\}\}$$

```
impDynConst1[[1]][[1]]
HurToJulia[%]
```

```
((Is+(2*lsa*lsb*(mb+(ms+2*mt))+((lsb)^(2)*(mb+(ms+2*mt))+(lsa)^(2)*(mb+2*(ms+mt)))))*
  q1dp+(F1*(lsa+lsb)*cos(q1)+(-1*(lsb*(mb+(ms+2*mt))+lsa*(mb+2*(ms+mt))))*q6dp*cos(q1)+
  ((lsa+lsb)*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt))))*q2dp*cos((q1+-1*q2))+(1/2*lb*(lsa+
  lsb)*mb*q3dp*cos((q1+-1*q3))+(-1*(lsa+lsb)*(lta*ms+ltb*(ms+mt)))*q4dp*cos((q1+-1*q4))
  +(-1*lsb*(lsa+lsb)*ms*q5dp*cos((q1+-1*q5))+(F2*(lsa+lsb)*sin(q1)+(-1*(lsb*(mb+(ms+2*
  mt))+lsa*(mb+2*(ms+mt))))*q7dp*sin(q1)+(-1*(Is+(2*lsa*lsb*(mb+(ms+2*mt))+((lsb)^(2)*
  (mb+(ms+2*mt))+(lsa)^(2)*(mb+2*(ms+mt)))))*q1d+(-1*(lsa+lsb)*(ltb*(mb+(ms+mt))+lta*
  (mb+(ms+2*mt))))*cos((q1+-1*q2))*q2d+(-1/2*lb*(lsa+lsb)*mb*cos((q1+-1*q3))*q3d+((lsa+
  lsb)*(lta*ms+ltb*(ms+mt))*cos((q1+-1*q4))*q4d+lsb*(lsa+lsb)*ms*cos((q1+-1*q5))*q5d))
  ))))))))))))
```

```
impDynConst1[[2]][[1]]
HurToJulia[%]
```

```
((It+(2*lta*ltb*(mb+(ms+mt))+((ltb)^(2)*(mb+(ms+mt))+(lta)^(2)*(mb+(ms+2*mt)))))*q2dp
  +((lsa+lsb)*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt))))*q1dp*cos((q1+-1*q2))+(F1*(lta+ltb)
  *cos(q2)+(-1*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt))))*q6dp*cos(q2)+(1/2*lb*(lta+ltb)*mb
  *q3dp*cos((q2+-1*q3))+(-1*(lta+ltb)*(lta*ms+ltb*(ms+mt)))*q4dp*cos((q2+-1*q4))+(-1*
  lsb*(lta+ltb)*ms*q5dp*cos((q2+-1*q5))+(F2*(lta+ltb)*sin(q2)+(-1*(ltb*(mb+(ms+mt))+
  lta*(mb+(ms+2*mt))))*q7dp*sin(q2)+(-1*(lsa+lsb)*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt))))
  *cos((q1+-1*q2))*q1d+(-1*(It+(2*lta*ltb*(mb+(ms+mt))+((ltb)^(2)*(mb+(ms+mt))+(lta)^
  (2)*(mb+(ms+2*mt)))))*q2d+(-1/2*lb*(lta+ltb)*mb*cos((q2+-1*q3))*q3d+((lta+ltb)*(lta
  *ms+ltb*(ms+mt))*cos((q2+-1*q4))*q4d+lsb*(lta+ltb)*ms*cos((q2+-1*q5))*q5d))))))))))
  )))
```

```
impDynConst1[[3]][[1]]
HurToJulia[%]
```

```
1/2*(2*(Ib+1/4*(lb)^(2)*mb)*q3dp+(lb*(lsa+lsb)*mb*q1dp*cos((q1+-1*q3))+(lb*(lta+ltb)*
  mb*q2dp*cos((q2+-1*q3))+(-1*lb*mb*q6dp*cos(q3)+(-1*lb*mb*q7dp*sin(q3)+(-1*lb*(lsa+
  lsb)*mb*cos((q1+-1*q3))*q1d+(-1*lb*(lta+ltb)*mb*cos((q2+-1*q3))*q2d+-2*(Ib+1/4*(lb)^
  (2)*mb)*q3d))))))
```

```
impDynConst1[[4]][[1]]
HurToJulia[%]
```

```
((It+((lta)^(2)*ms+(2*lta*ltb*ms+(ltb)^(2)*(ms+mt))))*q4dp+(-1*(lsa+lsb)*(lta*ms+ltb*(
  ms+mt))*q1dp*cos((q1+-1*q4))+(-1*(lta+ltb)*(lta*ms+ltb*(ms+mt)))*q2dp*cos((q2+-1*q4))
  +(-1*F1*(lta+ltb)*cos(q4)+((lta*ms+ltb*(ms+mt))*q6dp*cos(q4)+(lsb*(lta+ltb)*ms*q5dp*
  cos((q4+-1*q5))+(-1*F2*(lta+ltb)*sin(q4)+((lta*ms+ltb*(ms+mt))*q7dp*sin(q4)+((lsa+
  lsb)*(lta*ms+ltb*(ms+mt))*cos((q1+-1*q4))*q1d+((lta+ltb)*(lta*ms+ltb*(ms+mt))*cos((
  q2+-1*q4))*q2d+(-1*(It+((lta)^(2)*ms+(2*lta*ltb*ms+(ltb)^(2)*(ms+mt))))*q4d+-1*lsb*
  (lta+ltb)*ms*cos((q4+-1*q5))*q5d))))))))))
```

```
impDynConst1[[5]][[1]]
HurToJulia[%]
```

```
((Is+(lsb)^(2)*ms)*q5dp+(-1*lsb*(lsa+lsb)*ms*q1dp*cos((q1+-1*q5))+(-1*lsb*(lta+ltb)*ms
  *q2dp*cos((q2+-1*q5))+(lsb*(lta+ltb)*ms*q4dp*cos((q4+-1*q5))+(-1*F1*(lsa+lsb)*cos(q5
  )+(lsb*ms*q6dp*cos(q5)+(-1*F2*(lsa+lsb)*sin(q5)+(lsb*ms*q7dp*sin(q5)+(lsb*(lsa+lsb)*
  ms*cos((q1+-1*q5))*q1d+(lsb*(lta+ltb)*ms*cos((q2+-1*q5))*q2d+(-1*lsb*(lta+ltb)*ms*
  cos((q4+-1*q5))*q4d+-1*(Is+(lsb)^(2)*ms)*q5d))))))))))))
```

```
impDynConst1[[6]][[1]]
HurToJulia[%]
```

```
(-1*F1+((mb+2*(ms+mt))*q6dp+(-1*(lsb*(mb+(ms+2*mt))+lsa*(mb+2*(ms+mt)))*q1dp*cos(q1)+(
  -1*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*q2dp*cos(q2)+(-1/2*lb*mb*q3dp*cos(q3)+((lta
  *ms+ltb*(ms+mt))*q4dp*cos(q4)+(lsb*ms*q5dp*cos(q5)+((lsb*(mb+(ms+2*mt))+lsa*(mb+2*(
  ms+mt)))*cos(q1)*q1d+((ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*cos(q2)*q2d+(1/2*lb*mb*
  cos(q3)*q3d+(-1*(lta*ms+ltb*(ms+mt))*cos(q4)*q4d+-1*lsb*ms*cos(q5)*q5d)))))))))))
```

```
impDynConst1[[7]][[1]]
HurToJulia[%]
```

```
(-1*F2+((mb+2*(ms+mt))*q7dp+(-1*(lsb*(mb+(ms+2*mt))+lsa*(mb+2*(ms+mt)))*q1dp*sin(q1)+(
  -1*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*q2dp*sin(q2)+(-1/2*lb*mb*q3dp*sin(q3)+((lta
  *ms+ltb*(ms+mt))*q4dp*sin(q4)+(lsb*ms*q5dp*sin(q5)+((lsb*(mb+(ms+2*mt))+lsa*(mb+2*(
  ms+mt)))*sin(q1)*q1d+((ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*sin(q2)*q2d+(1/2*lb*mb*
  sin(q3)*q3d+(-1*(lta*ms+ltb*(ms+mt))*sin(q4)*q4d+-1*lsb*ms*sin(q5)*q5d)))))))))))
```

```
impDynConst2[[1]][[1]]
HurToJulia[%]
```

```
q6dp - (lsa + lsb) q1dp Cos[q1[t]] - (lta + ltb) q2dp Cos[q2[t]] +
  (lta + ltb) q4dp Cos[q4[t]] + (lsa + lsb) q5dp Cos[q5[t]]
```

```
(q6dp+(-1*(lsa+lsb)*q1dp*cos(q1)+(-1*(lta+ltb)*q2dp*cos(q2)+((lta+ltb)*q4dp*cos(q4)+(
  lsa+lsb)*q5dp*cos(q5)))))
```

```
impDynConst2[[2]][[1]]
HurToJulia[%]
```

```
q7dp - (lsa + lsb) q1dp Sin[q1[t]] - (lta + ltb) q2dp Sin[q2[t]] +
  (lta + ltb) q4dp Sin[q4[t]] + (lsa + lsb) q5dp Sin[q5[t]]
```

```
(q7dp+(-1*(lsa+lsb)*q1dp*sin(q1)+(-1*(lta+ltb)*q2dp*sin(q2)+((lta+ltb)*q4dp*sin(q4)+(
  lsa+lsb)*q5dp*sin(q5)))))
```

```
lambda1 = HurGlobalELEquation[[6]] /.
  {q6[t] → 0, q7[t] → 0, q6'[t] → 0, q7'[t] → 0, q6''[t] → 0, q7''[t] → 0}
HurToJulia[lambda1]
```

```
((lsb*(mb+(ms+2*mt))+lsa*(mb+2*(ms+mt)))*sin(q1)*(q1d)^(2)+((ltb*(mb+(ms+mt))+lta*(mb+
  (ms+2*mt)))*sin(q2)*(q2d)^(2)+(1/2*lb*mb*sin(q3)*(q3d)^(2)+(-1*lta*ms*sin(q4)*(q4d)^
  (2)+(-1*ltb*ms*sin(q4)*(q4d)^(2)+(-1*ltb*mt*sin(q4)*(q4d)^(2)+(-1*lsb*ms*sin(q5)*(
  q5d)^(2)+(-1*lsa*mb*cos(q1)*q1dd+(-1*lsb*mb*cos(q1)*q1dd+(-2*lsa*ms*cos(q1)*q1dd+(-1
  *lsb*ms*cos(q1)*q1dd+(-2*lsa*mt*cos(q1)*q1dd+(-2*lsb*mt*cos(q1)*q1dd+(-1*lta*mb*cos(
  q2)*q2dd+(-1*ltb*mb*cos(q2)*q2dd+(-1*lta*ms*cos(q2)*q2dd+(-1*ltb*ms*cos(q2)*q2dd+(-2
  *lta*mt*cos(q2)*q2dd+(-1*ltb*mt*cos(q2)*q2dd+(-1/2*lb*mb*cos(q3)*q3dd+(lta*ms*cos(q4
  )*q4dd+(ltb*ms*cos(q4)*q4dd+(ltb*mt*cos(q4)*q4dd+lsb*ms*cos(q5)*q5dd)))))))))))))))
  )))))))
```

```
lambda2 = HurGlobalELEquation[[7]] /.
  {q6[t] → 0, q7[t] → 0, q6'[t] → 0, q7'[t] → 0, q6''[t] → 0, q7''[t] → 0}
HurToJulia[lambda2]
```

```
(g*mb+(2*g*ms+(2*g*mt+(-1*(lsb*(mb+(ms+2*mt))+lsa*(mb+2*(ms+mt)))*cos(q1)*(q1d)^(2)+(
  -1*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*cos(q2)*(q2d)^(2)+(-1/2*lb*mb*cos(q3)*(q3d)
  ^(2)+(lta*ms*cos(q4)*(q4d)^(2)+(ltb*ms*cos(q4)*(q4d)^(2)+(ltb*mt*cos(q4)*(q4d)^(2)+(
  lsb*ms*cos(q5)*(q5d)^(2)+(-1*lsa*mb*sin(q1)*q1dd+(-1*lsb*mb*sin(q1)*q1dd+(-2*lsa*ms*
  sin(q1)*q1dd+(-1*lsb*ms*sin(q1)*q1dd+(-2*lsa*mt*sin(q1)*q1dd+(-2*lsb*mt*sin(q1)*q1dd
  +(-1*lta*mb*sin(q2)*q2dd+(-1*ltb*mb*sin(q2)*q2dd+(-1*lta*ms*sin(q2)*q2dd+(-1*ltb*ms*
  sin(q2)*q2dd+(-2*lta*mt*sin(q2)*q2dd+(-1*ltb*mt*sin(q2)*q2dd+(-1/2*lb*mb*sin(q3)*
  q3dd+(lta*ms*sin(q4)*q4dd+(ltb*ms*sin(q4)*q4dd+(ltb*mt*sin(q4)*q4dd+lsb*ms*sin(q5)*
  q5dd))))))))))))))))))))))))))))))
```

```
ImpactLHS = ArrayFlatten[{{HurGlobalMMatrix, -Transpose[JacFootSW]},
    {JacFootSW, Table[0, {i, 2}, {j, 2}]}}] // Simplify
HurToJulia[ImpactLHS]
```

```
[(Is+(2*lsa*lsb*(mb+(ms+2*mt))+((lsb)^(2)*(mb+(ms+2*mt))+(lsa)^(2)*(mb+2*(ms+mt)))))
  (lsa+lsb)*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*cos((q1+-1*q2))
  1/2*lb*(lsa+lsb)*mb*cos((q1+-1*q3))
  -1*(lsa+lsb)*(lta*ms+ltb*(ms+mt))*cos((q1+-1*q4))
  -1*lsb*(lsa+lsb)*ms*cos((q1+-1*q5))
  -1*(lsb*(mb+(ms+2*mt))+lsa*(mb+2*(ms+mt)))*cos(q1)
  -1*(lsb*(mb+(ms+2*mt))+lsa*(mb+2*(ms+mt)))*sin(q1) (lsa+lsb)*cos(q1)
  (lsa+lsb)*sin(q1);(lsa+lsb)*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*cos((q1+-1*q2))
  (It+(2*lta*ltb*(mb+(ms+mt))+((ltb)^(2)*(mb+(ms+mt))+(lta)^(2)*(mb+(ms+2*mt)))))
  1/2*lb*(lta+ltb)*mb*cos((q2+-1*q3))
  -1*(lta+ltb)*(lta*ms+ltb*(ms+mt))*cos((q2+-1*q4))
  -1*lsb*(lta+ltb)*ms*cos((q2+-1*q5))
  -1*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*cos(q2)
  -1*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*sin(q2) (lta+ltb)*cos(q2)
  (lta+ltb)*sin(q2);1/2*lb*(lsa+lsb)*mb*cos((q1+-1*q3))
  1/2*lb*(lta+ltb)*mb*cos((q2+-1*q3)) (Ib+1/4*(lb)^(2)*mb) 0 0 -1/2*lb*mb*cos(q3)
  -1/2*lb*mb*sin(q3) 0 0;-1*(lsa+lsb)*(lta*ms+ltb*(ms+mt))*cos((q1+-1*q4))
  -1*(lta+ltb)*(lta*ms+ltb*(ms+mt))*cos((q2+-1*q4)) 0
  (It+((lta)^(2)*ms+(2*lta*ltb*ms+(ltb)^(2)*(ms+mt))))
  lsb*(lta+ltb)*ms*cos((q4+-1*q5)) (lta*ms+ltb*(ms+mt))*cos(q4)
  (lta*ms+ltb*(ms+mt))*sin(q4) -1*(lta+ltb)*cos(q4)
  -1*(lta+ltb)*sin(q4);-1*lsb*(lsa+lsb)*ms*cos((q1+-1*q5))
  -1*lsb*(lta+ltb)*ms*cos((q2+-1*q5)) 0 lsb*(lta+ltb)*ms*cos((q4+-1*q5))
  (Is+(lsb)^(2)*ms) lsb*ms*cos(q5) lsb*ms*sin(q5) -1*(lsa+lsb)*cos(q5)
  -1*(lsa+lsb)*sin(q5);-1*(lsb*(mb+(ms+2*mt))+lsa*(mb+2*(ms+mt)))*cos(q1)
  -1*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*cos(q2) -1/2*lb*mb*cos(q3)
  (lta*ms+ltb*(ms+mt))*cos(q4) lsb*ms*cos(q5) (mb+2*(ms+mt))
  0 -1 0;-1*(lsb*(mb+(ms+2*mt))+lsa*(mb+2*(ms+mt)))*sin(q1)
  -1*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*sin(q2)
  -1/2*lb*mb*sin(q3) (lta*ms+ltb*(ms+mt))*sin(q4) lsb*ms*sin(q5) 0
  (mb+2*(ms+mt)) 0 -1;-1*(lsa+lsb)*cos(q1) -1*(lta+ltb)*cos(q2) 0
  (lta+ltb)*cos(q4) (lsa+lsb)*cos(q5) 1 0 0 0;-1*(lsa+lsb)*sin(q1)
  -1*(lta+ltb)*sin(q2) 0 (lta+ltb)*sin(q4) (lsa+lsb)*sin(q5) 0 1 0 0]
```

```
HurGlobalMMatrix.HurList2Column[{q1'[t], q2'[t], q3'[t], q4'[t], q5'[t], 0, 0}];
ImpactRHS = ArrayFlatten[{{%}, {0}, {0}}]
HurToJulia[ImpactRHS]
```

```
[((Is+(2*lsa*lsb*(mb+(ms+2*mt))+((lsb)^(2)*(mb+(ms+2*mt))+(lsa)^(2)*(mb+2*(ms+mt))))
  *q1d+((lsa+lsb)*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*cos((q1+-1*q2))*q2d+(1/2*lb*(
  lsa+lsb)*mb*cos((q1+-1*q3))*q3d+(-1*(lsa+lsb)*(lta*ms+ltb*(ms+mt))*cos((q1+-1*q4))*
  q4d+-1*lsb*(lsa+lsb)*ms*cos((q1+-1*q5))*q5d))));((lsa+lsb)*(ltb*(mb+(ms+mt))+lta*(mb
  +(ms+2*mt)))*cos((q1+-1*q2))*q1d+((It+(2*lta*ltb*(mb+(ms+mt))+((ltb)^(2)*(mb+(ms+mt
  ))+(lta)^(2)*(mb+(ms+2*mt))))*q2d+(1/2*lb*(lta+ltb)*mb*cos((q2+-1*q3))*q3d+(-1*(
  lta+ltb)*(lta*ms+ltb*(ms+mt))*cos((q2+-1*q4))*q4d+-1*lsb*(lta+ltb)*ms*cos((q2+-1*q5)
  )*q5d))));(1/2*lb*(lsa+lsb)*mb*cos((q1+-1*q3))*q1d+(1/2*lb*(lta+ltb)*mb*cos((q2+-1*
  q3))*q2d+(Ib+1/4*(lb)^(2)*mb)*q3d));(-1*(lsa+lsb)*(lta*ms+ltb*(ms+mt))*cos((q1+-1*q4
  ))*q1d+(-1*(lta+ltb)*(lta*ms+ltb*(ms+mt))*cos((q2+-1*q4))*q2d+((It+((lta)^(2)*ms+(2
  *lta*ltb*ms+(ltb)^(2)*(ms+mt))))*q4d+lsb*(lta+ltb)*ms*cos((q4+-1*q5))*q5d)));(-1*lsb
  *(lsa+lsb)*ms*cos((q1+-1*q5))*q1d+(-1*lsb*(lta+ltb)*ms*cos((q2+-1*q5))*q2d+(lsb*(lta
  +ltb)*ms*cos((q4+-1*q5))*q4d+(Is+(lsb)^(2)*ms)*q5d)));(-1*(lsb*(mb+(ms+2*mt))+lsa*(
  mb+2*(ms+mt)))*cos(q1)*q1d+(-1*(ltb*(mb+(ms+mt))+lta*(mb+(ms+2*mt)))*cos(q2)*q2d+(-1
  /2*lb*mb*cos(q3)*q3d+((lta*ms+ltb*(ms+mt))*cos(q4)*q4d+lsb*ms*cos(q5)*q5d))));(-1*(
  lsb*(mb+(ms+2*mt))+lsa*(mb+2*(ms+mt)))*sin(q1)*q1d+(-1*(ltb*(mb+(ms+mt))+lta*(mb+(ms
  +2*mt)))*sin(q2)*q2d+(-1/2*lb*mb*sin(q3)*q3d+((lta*ms+ltb*(ms+mt))*sin(q4)*q4d+lsb*
  ms*sin(q5)*q5d))));0;0]
```

```
Dimensions[HurGlobalMMatrix]
```

```
{7, 7}
```

```
JacFootSW // MatrixForm
```

$$\begin{pmatrix} -\left(\text{lsa}+\text{lsb}\right)\text{Cos}[\text{q1}[\text{t}]] & -\left(\text{lta}+\text{ltb}\right)\text{Cos}[\text{q2}[\text{t}]] & 0 & \left(\text{lta}+\text{ltb}\right)\text{Cos}[\text{q4}[\text{t}]] & \left(\text{lsa}+\text{lsb}\right)\text{Cos}[\text{q5}[\\ -\left(\text{lsa}+\text{lsb}\right)\text{Sin}[\text{q1}[\text{t}]] & -\left(\text{lta}+\text{ltb}\right)\text{Sin}[\text{q2}[\text{t}]] & 0 & \left(\text{lta}+\text{ltb}\right)\text{Sin}[\text{q4}[\text{t}]] & \left(\text{lsa}+\text{lsb}\right)\text{Sin}[\text{q5}[\end{pmatrix}$$

```
HurSaveData["data_imp_1.m", "FootST", "ShankSTCOM", "KneeST", "ThighSTCOM",
 "Hip", "TorsoCOM", "ThighSWCOM", "KneeSW", "ShankSWCOM", "FootSW", "dyn1",
 "dyn2", "dyn3", "dyn4", "dyn5", "stepLength", "stepHeight", "JacFootSW",
 "impDynConst1", "impDynConst2", "lambda1", "lambda2", "ImpactLHS", "ImpactRHS"]
```