# APPENDIX B – MODEL PARAMETER SCRIPTS

```
#----------------------------------------------------------------------------
#
# file:  human.bones
#
# Skeleton for human model with feet, arms and 2-link torso.
# All joints are 1 DOF, except for hips (3 DOF) and ankles (2 DOF).
# Mass and inertia data from Wooten & Hodgens
#
# Body axes:  forward -> -1,0,0   (-ve x-axis)
#             right   -> 0,0,-1   (-ve z-axis)
#             up      -> 0,1,0    (+ve y-axis)
#
# Joints:  (z - pitch, x - roll, y - yaw)
#   waist-z,spine-z,neck-z,lhip-x, lhip-z, lhip-y, lknee-z, lankle-z, lankle-x
#                          rhip-x, rhip-z, rhip-y, rknee-z, rankle-z, rankle-x
#                          lshoulder-z, lelbow-z, rshoulder-z, relbow-z
#
#
# Model construction commands:
# ----------------------------
#
#    bone <#>
#        Creatues a new bone.  Bones can have many rigidly attached segments.
#    seg <x1>,<y1>,<z1> <x2>,<y2>,<z2>
#        Adds a segment to the current bone.
#    cofm <x> <y> <z> <rx> <ry> <rz>
#        Specifies the centre of mass for the current bone.
#    mass <mass>
#        Specifies the mass for the current bone.
#    iner <ix> <iy> <iz>
#        Specifies the moment of inertia for the current bone about major axes
#    mon <x>,<y>,<z>
#        Specifies a monitor point
#    hinge <bone#> <x>,<y>,<z> <ax>,<ay>,<az>
#        Specifies a 1 DOF hinge at x,y,z with axis ax,ay,az
#    uhinge and ghinge
#        Similar to hinge but specify 2 DOF and 3 DOF respectively
#        and take 2 and 3 hinge axis arguments respectively.
#    kpd hinge <parent bone #>:<DOF#>   <Kp>  <Kd>
#    mon <x>,<y>,<z>
#        Adds a new monitor point at x,y,z.  Monitor points are points of
#        interest on the creature.  They are the only parts of a creature
#        which are experience ground forces.
#
#----------------------------------------------------------------------------


### STRUCTURE + LINK PARAMETERS  ---------------------------------------------

bone 1                                            # pelvis
seg  0,0.95,0.12  0,0.95,-0.12                    #  - add a bone segment
mass 16.61                                        #  - bone mass
iner 0.23  0.16  0.18                             #  - major axis inertias
cofm 0  0.98  0                                   #  - bone COM position
```

```
bone 2                                                # lower torso
seg 0,1.02,0  0,1.35,0
mass 19.5133
iner 0.4867  0.17427  0.42
cofm -0.03  1.3112  0
hinge 1  0,1.0202,0  0,0,1                            # waist - 1 DOF (pitch)

bone 3                                                # upper torso
seg 0,1.35,0  0,1.505,0
mass 9.7567
iner 0.2433  0.08713  0.21
cofm -0.03  1.4275  0
hinge 2  0,1.35,0  0,0,1                              # spine - 1 DOF (pitch)

bone 4                                                # head
seg 0.02,1.57,0  0.02,1.80,0
mass 5.89
iner 0.03  0.023  0.033
cofm -0.01  1.70  0
hinge 3  0.0478,1.5052,0  0,0,1                       # neck - 1 DOF (pitch)

bone 5                                                # left upper leg
seg 0.00478,0.9629,0.0932 0.00478,0.5197,0.09091
mass 8.35
iner 0.15 0.025 0.16
cofm 0 0.80 0.09
ghinge 1 0.00478,0.9629,0.0932 1,0,0 0,0,1 0,1,0     # hip - 3 DOF
                                                      #       (roll, pitch, yaw)

bone 6                                                # left lower leg
seg 0.00478,0.5197,0.09091 0.03348,0.09164,0.0837
mass 4.16
iner 0.055 0.007 0.056
cofm 0 0.35 0.07
hinge 5 0.00478,0.5197,0.09091 0,0,1                  # knee - 1 DOF (pitch)

bone 7                                                # left foot
seg -0.10,0,0.0837 0.07,0,0.0837
mass 1.20
iner 0.0018 0.0070 0.0075
cofm -0.03 0.02 0.08
uhinge 6 0.03348,0.09164,0.0837 0,0,1 1,0,0           # ankle - 2 DOF
                                                      #         (pitch, roll)

bone 8                                                # right upper leg
seg 0.00478,0.9629,-0.0932 0.00478,0.5197,-0.09091
mass 8.35
iner 0.15 0.025 0.16
cofm 0 0.80 -0.09
ghinge 1 0.00478,0.9629,-0.0932 1,0,0 0,0,1 0,1,0    # hip - 3 DOF
                                                      #       (roll, pitch, yaw)

bone 9                                                # right lower leg
seg 0.00478,0.5197,-0.09091 0.03348,0.09164,-0.0837
mass 4.16
iner 0.055 0.007 0.056
cofm 0 0.35 -0.07
hinge 8 0.00478,0.5197,-0.09091 0,0,1                 # knee - 1 DOF (pitch)

bone 10                                               # right foot
seg -0.10,0,-0.0837 0.07,0,-0.0837
mass 1.20
iner 0.0018 0.0070 0.0075
cofm -0.03 0.02 -0.08
```

```
uhinge 9 0.03348,0.09164,-0.0837 0,0,1 1,0,0        # ankle - 2 DOF ankle
                                                     #         (pitch, roll)

bone 11                                              # left upper arm
seg 0.0289,1.4203,0.1847 0.0287,1.1491,0.2102
mass 2.79
iner 0.025 0.005 0.025
cofm 0 1.34 0.21
hinge 3 0.02,1.4203,0.1847 0,0,1                     # shoulder - 1 DOF (pitch)

bone 12                                              # left lower arm
seg 0.0287,1.1491,0.2102 0.0287,0.85,0.2302
mass 1.761
iner 0.0066 0.0018 0.0080
cofm 0.0287 1.03 0.222
hinge 11 0.0287,1.1491,0.2102 0,0,1                  # elbow - 1 DOF (pitch)

bone 13                                              # right upper arm
seg 0.0289,1.4203,-0.1847 0.0287,1.1491,-0.2102
mass 2.79
iner 0.025 0.005 0.025
cofm 0 1.34 -0.21
hinge 3 0.02,1.4203,-0.1847 0,0,1                    # shoulder - 1 DOF (pitch)

bone 14                                              # right lower arm
seg 0.0287,1.1491,-0.2102 0.0287,0.85,-0.2302
mass 1.761
iner 0.0066 0.0018 0.0080
cofm 0.0287 1.03 -0.222
hinge 13 0.0287,1.1491,-0.2102 0,0,1                 # elbow - 1 DOF (pitch)


### JOINT STRENGTH (Kp & Kd) PARAMETERS  ------------------------------------

kpd hinge 2:0  2000 100                              # waist pitch (z)
kpd hinge 3:0  2000 100                              # spine pitch (z)
kpd hinge 4:0   100  10                              # neck pitch (z)

kpd hinge 5:0   900  30                              # left hip roll (x)
kpd hinge 5:1  1275  60                              # left hip pitch (z)
kpd hinge 5:2  1275  60                              # left hip yaw (y)

kpd hinge 6:0  1275  60                              # left knee pitch (z)

kpd hinge 7:0   170  17                              # left ankle pitch (z)
kpd hinge 7:1   170  17                              # left ankle roll (x)


kpd hinge 8:0   900  30                              # right hip roll (x)
kpd hinge 8:1  1275  60                              # right hip pitch (z)
kpd hinge 8:2  1275  60                              # right hip yaw (y)

kpd hinge 9:0  1275  60                              # right knee pitch (z)

kpd hinge 10:0  170  17                              # right ankle pitch (z)
kpd hinge 10:1  170  17                              # right ankle roll (x)


kpd hinge 11:0  100 10                               # left shoulder pitch (z)
kpd hinge 12:0   50  5                               # left elbow pitch (z)

kpd hinge 13:0  100 10                               # right shoulder pitch (z)
kpd hinge 14:0   50  5                               # right elbow pitch (z)
```

```
### MONITOR POINTS  -------------------------------------------------------

                                                    # up vector monitor
                                                    # points (lower torso):
mon 0,1.1,0                                         #  1 - origin
mon 0,1.3,0                                         #  2 - "up"
mon 0,1.1,-.05                                      #  3 - "right"

                                                    # swing/stance COM points:
mon 0.03348,0,0.0837                                #  4 - left mid-foot
mon 0.03348,0,-0.0837                               #  5 - right mid-foot

                                                    #      left foot:
mon -0.10,0,0.05                                    #  6 - inside ball of foot
mon 0.07,0,0.05                                     #  7 - inside heel
mon 0.07,0,0.13                                     #  8 - outside heel
mon -0.10,0,0.13                                    #  9 - little toe

                                                    #      right foot:
mon -0.10,0,-0.05                                   # 10 - inside ball of foot
mon 0.07,0,-0.05                                    # 11 - inside heel
mon 0.07,0,-0.13                                    # 12 - outside heel
mon -0.10,0,-0.13                                   # 13 - little toe

mon 0.00478,0.5197,0.09091                          # 14 - left knee
mon 0.00478,0.5197,-0.09091                         # 15 - right knee

mon 0.02,1.80,0                                     # 16 - head

                                                    # pelvis-based up vector &
                                                    # torso servo mon points:
mon 0,0.95,0                                        # 17 - origin
mon 0,0.97,0                                        # 18 - "up"
mon 0,0.95,-.02                                     # 19 - "right"
mon 0,0.95,+.02                                     # 20 - servo axis (local)
mon 0,1.1,+.05                                      # 21 - torso axis


set up_mon 1,2,3                                    # up vect mon points
set cofm_mon 5,4                                    # initial swing,stance feet
```

```
#----------------------------------------------------------------------------
#
# file:  robo-bird.bones
#
# Skeleton for bird-like robot model with feet, body and large head.
# All joints are 1 DOF, except for hips (2 DOF) and ankles (2 DOF).
# Mass and inertia parameters calculated automatically using density of
# 1.0 g/cm^3
#
# Body axes:  forward -> -1,0,0   (-ve x-axis)
#             right   -> 0,0,-1   (-ve z-axis)
#             up      -> 0,1,0    (+ve y-axis)
#
# Joints:  (z - pitch, x - roll, y - yaw)
# neck-z, rhip-x, rhip-z, rknee1-z, rknee2-z, rknee3-z, rankle-z, rankle-x
#         lhip-x, lhip-z, lknee1-z, lknee2-z, lknee3-z, lankle-z, lankle-x
#
#----------------------------------------------------------------------------


### STRUCTURE + LINK PARAMETERS  --------------------------------------------

# the words "left" and "right" may be backwards in the descriptions below.

bone 1                                              # body
   # x-aligned segments
seg 1.0,-0.4,-1.5 -4,-0.4,-1.5
seg 1.0,-0.4,1.5 -4,-0.4,1.5
seg 1.0,0.8,-1.5 -4,0.8,-1.5
seg 1.0,0.8,1.5 -4,0.8,1.5
   # z-aligned segments
seg 1.0,0.8,-1.5 1.0,0.8,1.5
seg 1.0,-0.4,-1.5 1.0,-0.4,1.5
seg -4,-0.4,-1.5 -4,-0.4,1.5
seg -4,0.8,-1.5 -4,0.8,1.5
   # y-aligned segments
seg 1.0,-0.4,-1.5 1.0,0.8,-1.5
seg 1.0,-0.4,1.5 1.0,0.8,1.5
seg -4,-0.4,-1.5 -4,0.8,-1.5
seg -4,-0.4,1.5 -4,0.8,1.5

bone 2                                              # head
   # x-aligned segments
seg 0.5,1.5,-1.75 -6.0,1.5,-0.9
seg 0.5,1.5,1.75 -6.0,1.5,0.9
seg 0.5,5.5,-2.25 -4.5,5.5,-1.25
seg 0.5,5.5,2.25 -4.5,5.5,1.25
   # z-aligned segments
seg 0.5,1.5,-1.75 0.5,1.5,1.75
seg 0.5,5.5,-2.25 0.5,5.5,2.25
seg -6.0,1.5,-0.9 -6.0,1.5,0.9
seg -4.5,5.5,-1.25 -4.5,5.5,1.25
   # y-aligned segments
seg 0.5,1.5,-1.75 0.5,5.5,-2.25
seg 0.5,1.5,1.75 0.5,5.5,2.25
seg -6.0,1.5,-0.9 -4.5,5.5,-1.25
seg -6.0,1.5,0.9 -4.5,5.5,1.25
hinge 1 -2.3,1.0,0 0,1,0                            # neck - 1 DOF (yaw)

bone 3                                              # right leg bone1 (upper)
seg 0,0,-2.5 -3,0,-2.5
uhinge 1 0,0,-2.5 1,0,0 0,0,1                       # hip - 2 DOF
                                                    #       (roll, pitch)
```

```
bone 4                                              # right leg bone2 (mid1)
seg -3,0,-2.5 -3,-4,-2.5
hinge 3 -3,0,-2.5 0,0,1                             # knee1 - 1 DOF (pitch)

bone 5                                              # right leg bone3 (mid2)
seg -3,-4,-2.5 -3,-9.5,-2.5
hinge 4 -3,-4,-2.5 0,0,1                            # knee2 - 1 DOF (pitch)

bone 6                                              # right leg bone4 (lower)
seg -4.8,-9.5,-2.5 -1.3,-9.5,-2.5
hinge 5 -3,-9.5,-2.5 0,0,1                          # knee3 - 1 DOF (pitch)

bone 7                                              # right foot
seg -4.1,-10.4,-2.5 -7.6,-10.4,-2.5
seg -5.6,-10.4,-3.9 -5.6,-10.4,-1.1
uhinge 6 -4.8,-9.5,-2.5 0,0,1 1,0,0                 # ankle - 2 DOF
                                                    #         (pitch, roll)

bone 8                                              # left leg bone1 (upper)
seg 0,0,2.4 -3,0,2.4
uhinge 1 0,0,2.5 -1,0,0 0,0,1                       # hip - 2 DOF
                                                    #       (roll, pitch)

bone 9                                              # right leg bone2 (mid1)
seg -3,0,2.5 -3,-4,2.5
hinge 8 -3,0,2.5 0,0,1                              # knee1 - 1 DOF (pitch)

bone 10                                             # left leg bone3 (mid2)
seg -3,-4,2.5 -3,-9.5,2.5
hinge 9 -3,-4,2.5 0,0,1                             # knee2 - 1 DOF (pitch)

bone 11                                             # left leg bone4 (lower)
seg -4.8,-9.5,2.5 -1.3,-9.5,2.5
hinge 10 -3,-9.5,2.5 0,0,1                          # knee3 - 1 DOF (pitch)

bone 12                                             # left foot
seg -4.1,-10.4,2.5 -7.6,-10.4,2.5
seg -5.6,-10.4,1.1 -5.6,-10.4,3.9
uhinge 11 -4.8,-9.5,2.5 0,0,1 1,0,0                 # ankle - 2 DOF
                                                    #         (pitch, roll)


### JOINT STRENGTH PARAMETERS  ----------------------------------------------

kpd hinge 2    1000 33                              # neck pitch (z)


kpd hinge 3:0  1000 33                              # right hip roll (x)
kpd hinge 3:1  1000 33                              # right hip pitch (z)

kpd hinge 4    1000 33                              # right knee1 pitch (z)
kpd hinge 5    1000 33                              # right knee2 pitch (z)
kpd hinge 6    1000 33                              # right knee3 pitch (z)

kpd hinge 7:0   100  1.5                            # right ankle pitch (z)
kpd hinge 7:1   100  1.5                            # right ankle roll (x)


kpd hinge 8:0  1000 33                              # left hip roll (x)
kpd hinge 8:1  1000 33                              # left hip pitch (z)

kpd hinge 9    1000 33                              # left knee1 pitch (z)
kpd hinge 10   1000 33                              # left knee2 pitch (z)
kpd hinge 11   1000 33                              # left knee3 pitch (z)
```

```
kpd hinge 12:0  100  1.5                        # left ankle pitch (z)
kpd hinge 12:1  100  1.5                        # left ankle roll (x)


### MONITOR POINTS  ---------------------------------------------------------

                                                # right foot
mon -3.8,-10.4,-3.9                             #  1 - right/back
mon -3.8,-10.4,-1.1                             #  2 - left/back
mon -7.6,-10.4,-3.9                             #  3 - right/front
mon -7.6,-10.4,-1.1                             #  4 - left/back

                                                # left foot
mon -3.8,-10.4,3.9                              #  5 - left/back
mon -3.8,-10.4,1.1                              #  6 - right/back
mon -7.6,-10.4,3.9                              #  7 - left/front
mon -7.6,-10.4,1.1                              #  8 - right/front

                                                # falling & up vect mons:
mon -5.5,2,0                                    #  9 - nose
mon 1,2,0                                       # 10 - up vect origin
mon 1,3,0                                       # 11 - up vect "up"
mon 2,2,0                                       # 12 - up vect "right"
mon 1,2,0                                       # 13 - body

                                                # swing/stance COM points:
mon -4.8,-10.4,-2.5                             # 14 - right foot COM mon
mon -4.8,-10.4,2.5                              # 15 - left foot COM mon

set up_mon 10,11,13                             # up vect monitor points
set cofm_mon 15,14                              # initial swing,stance feet

kpd mon 14 0 0                                  # no gnd force on cofm_mon
kpd mon 15 0 0                                  # no gnd force on cofm_mon
```