MECH 6303 CAD Project Presentation

Humanoid Robot CAD model and Kinematics

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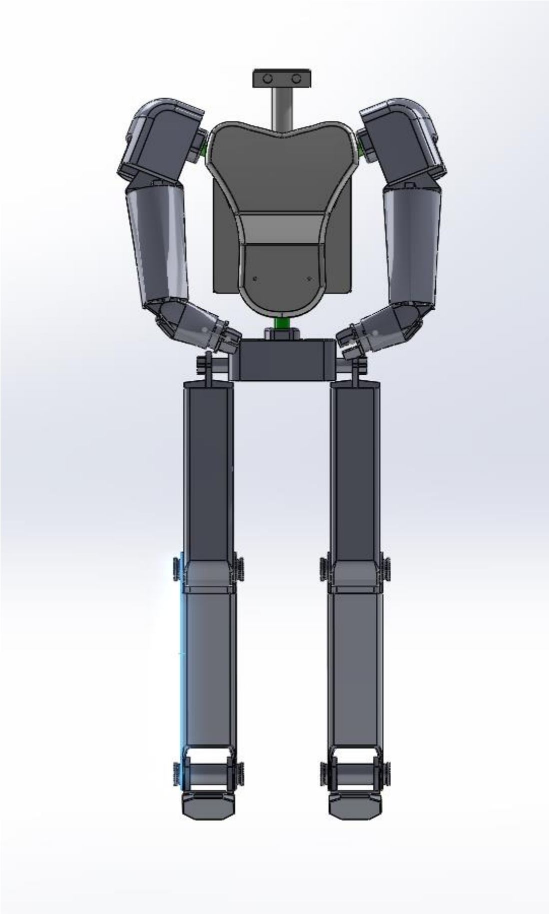
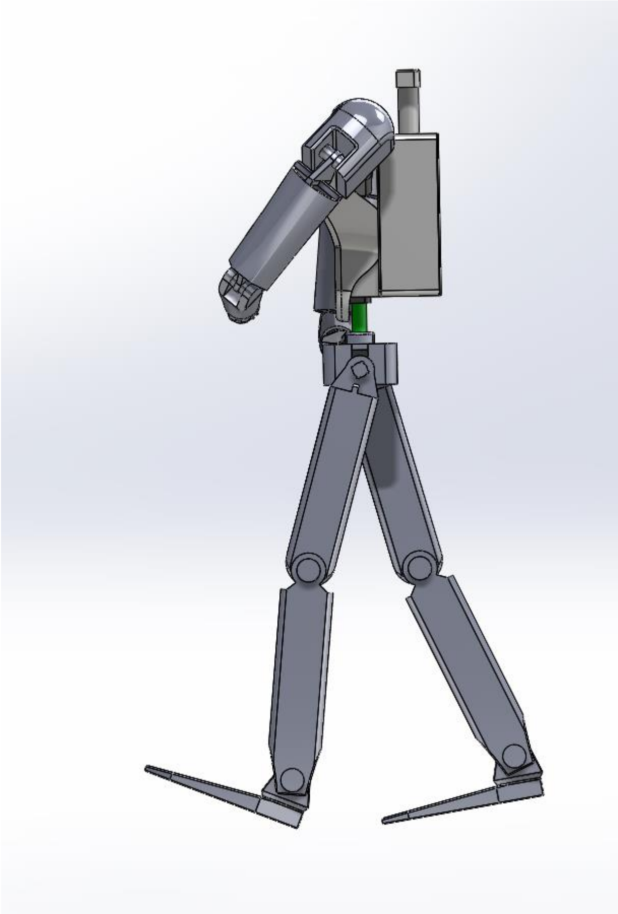
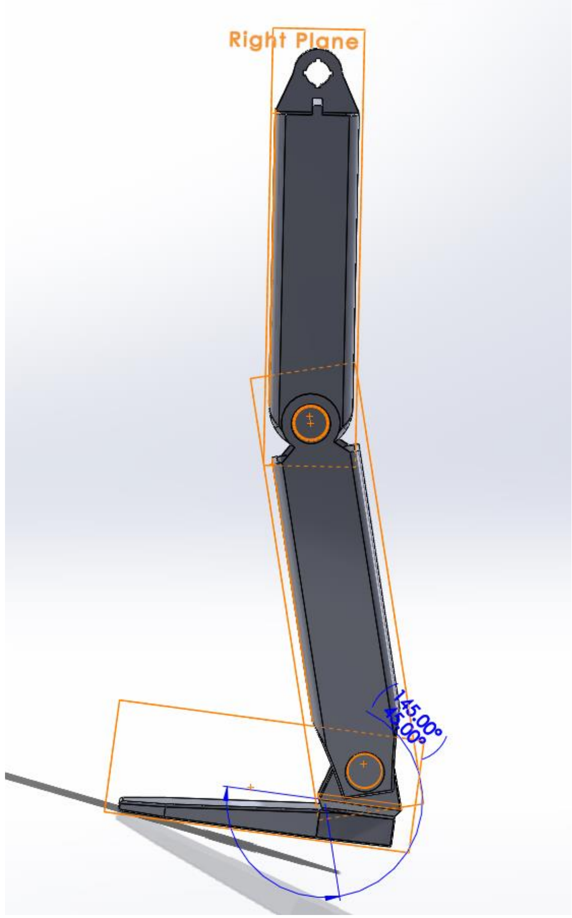
Front and Side view of the Robot CAD model

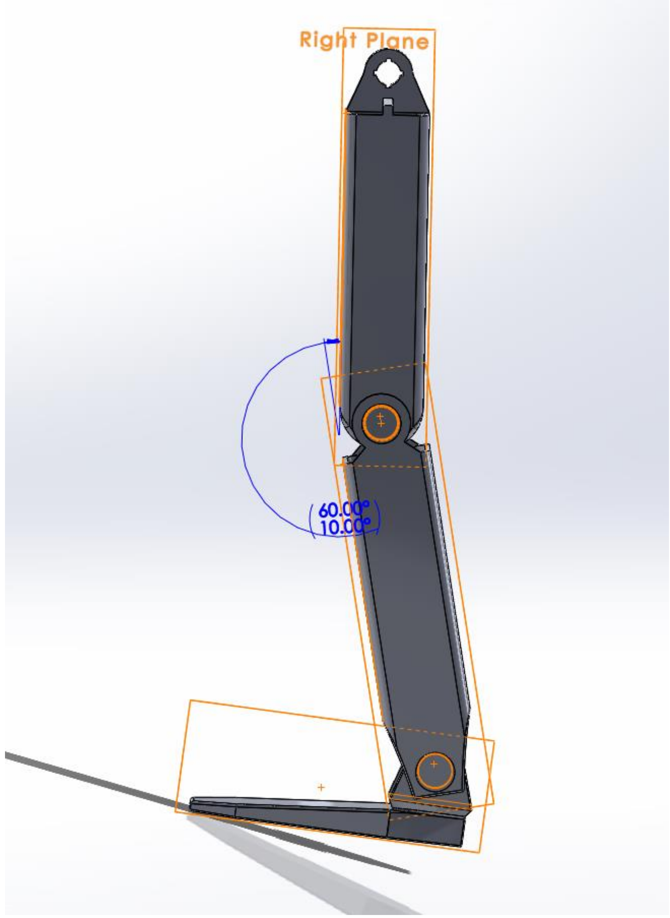




- 16 degrees of freedom excluding the grippers
- Total weight around 150 kg
- Height 4’6”

Limiting angles of the leg for the knee and ankle joints





The joints are limited in the range of the movement,
so that the leg does not reach any points of singularity

Forward kinematics for the leg using Mathematica

```
xi1=RevoluteTwist[{0,0,0},{0,0,1}];
xi2=RevoluteTwist[{l1,0,0},{0,0,1}];
xi3=RevoluteTwist[{l1+l2,0,0},{0,0,1}];
gs30=RPToHomogeneous[IdentityMatrix[3],{l1+l2+l3,0,0}]
gs3t=Simplify[ForwardKinematics[{xi1,th1[t]},{xi2,th2[t]},{xi3,th3[t]},gs30];
```

Assuming

```
l1=315;
l2=360;
l3=254;m=6;
```

(Solutions in the appendix)

Dynamics and equations of motion for the leg using Mathematica

Energy equations of the leg:

PE=FullSimplify[m*g*l1/2*Sin[th1[t]]+m*g*(l1*Sin[th1[t]]+l2/2*Sin[th1[t]+th2[t]])+m*g*(l1*Sin[th1[t]]+l2*Sin[th1[t]+th2[t]]+l3/2*Sin[th1[t]+th2[t]+th3[t]])]

KE=FullSimplify[(1/2)*Transpose[thd].Mmat.thd]

L=FullSimplify[KE-PE]

Euler-Lagrange's equation:

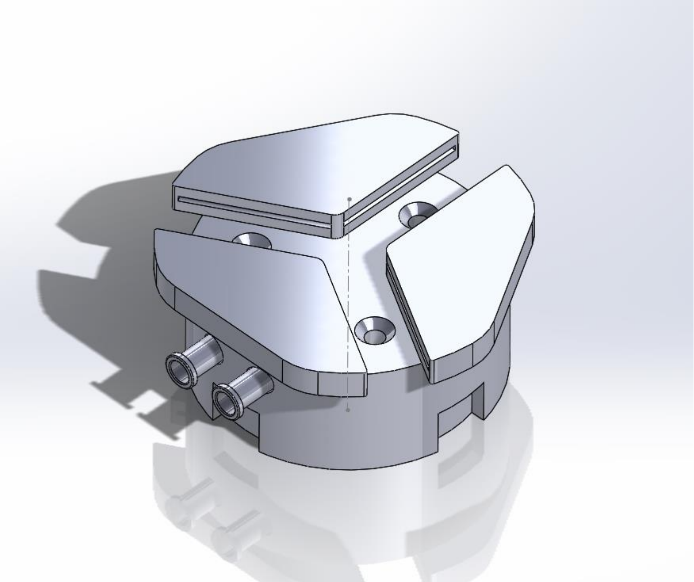
Eleqs=MatrixForm[FullSimplify[D[L,{thd},t]-D[L,{th}]]]

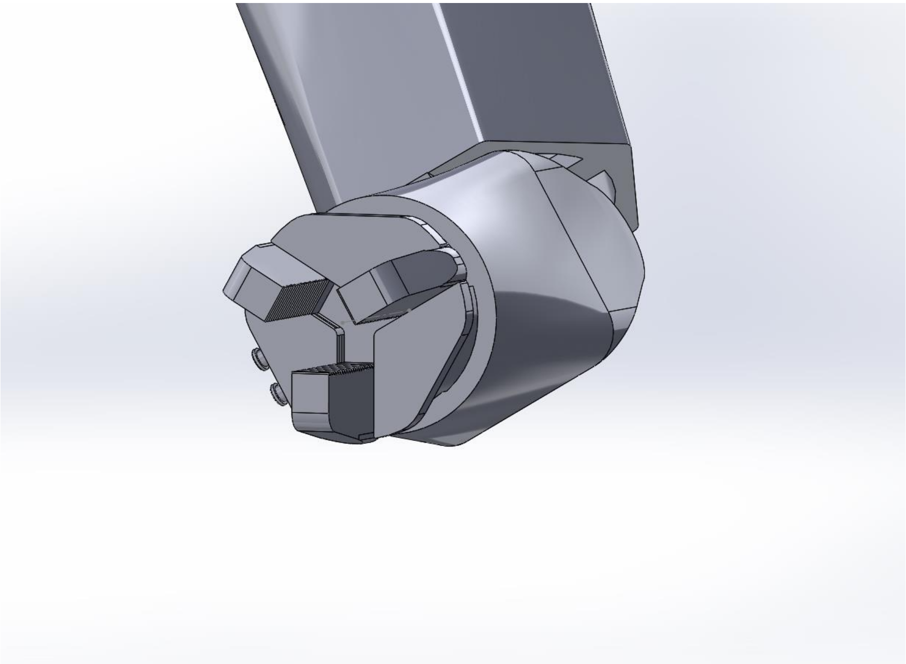
Matlab Code for two link dynamics

```
function dx=pdcontrol(t,x)

%%state variables
q1=x(1); q1dot=x(2); q2=x(3); q2dot=x(4);

%%define robot link parameters here

%%defining the desired positions at the top most point during motion

xd(1)=pi/4;
xd(2)=-pi/4;

%%forming the matrices for the equations of motion
D=[m1*lc1^2+m2*(l1^2+lc2^2+2*l1*lc2^2+2*l1*lc2*cos(x(3)))+I1+I2 m2*(lc2^2+l1*lc2*cos(x(3)))+I2;m2*(lc2^2+l1*lc2*cos(x(3)))+I2 
m2*lc2^2+I2];
h=-m2*l1*lc2*sin(x(3));
C=[h*x(4) h*(x(4)+x(2));-h*x(2) 0];
phi=[(m1*lc1+m2*l1)*g*cos(x(1))+m2*lc2*g*cos(x(1)+x(3)) m2*lc2*cos(x(1)+x(3))]';
tau1=kp1*(xd(1)-x(1))-kd1*x(2);
tau2=kp2*(xd(2)-x(3))-kd2*x(4);
if(tau1>=10)
    tau1=10;
end
if(tau1<=-10)
    tau1=-10;
end
if(tau2>=10)
    tau2=10;
end
if(tau2<=-10)
    tau2=-10;
end
tau=[tau1 tau2]';

%%equations of motion
qdot=[x(2) x(4)]';
qdoubledot=D\(tau-C*qdot-phi);

dx=[q1dot qdoubledot(1) q2dot qdoubledot(2)]';
end
```

Gripper Specifications

- Centric, three-finger pneumatic gripper
- 6mm travel for each finger of the gripper





Tools used

- SolidWorks
- Wolfram Mathematica
- Matlab

References

- Screw theory for forward kinematics:

A Mathematical Introduction to Robotic Manipulation

Richard M. Murray, Zexiang Li, S. Shankar Sastry

- Robot Modeling and Control

Mark W. Spong, Seth Hutchinson, and M. Vidyasagar,

- Reference images for the robot: Atlas Robot models, Boston Dynamics

Appendix

- gs30={{1,0,0,929},{0,1,0,0},{0,0,1,0},{0,0,0,1}}
- gs3t= {{Cos[th1[t]+th2[t]+th3[t]],-Sin[th1[t]+th2[t]+th3[t]],0,315 Cos[th1[t]]+360 Cos[th1[t]+th2[t]]+254 Cos[th1[t]+th2[t]+th3[t]]},{Sin[th1[t]+th2[t]+th3[t]],Cos[th1[t]+th2[t]+ th3[t]],0,315 Sin[th1[t]]+360 Sin[th1[t]+th2[t]]+254 Sin[th1[t]+th2[t]+th3[t]]},{0,0,1,0},{0,0,0,1}}
- This gives the end position of the toe with respect to the hip. If we need only the position of the heel we can do the same analysis for only two links.