



Ball on Plate

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Project Description: Ball on Plate

- A ball is placed on a plate and made not to roll off
- The tilt of the plate is controlled in two dimensions by servo motors
- The servo motors are connected by PID controllers

Modeling

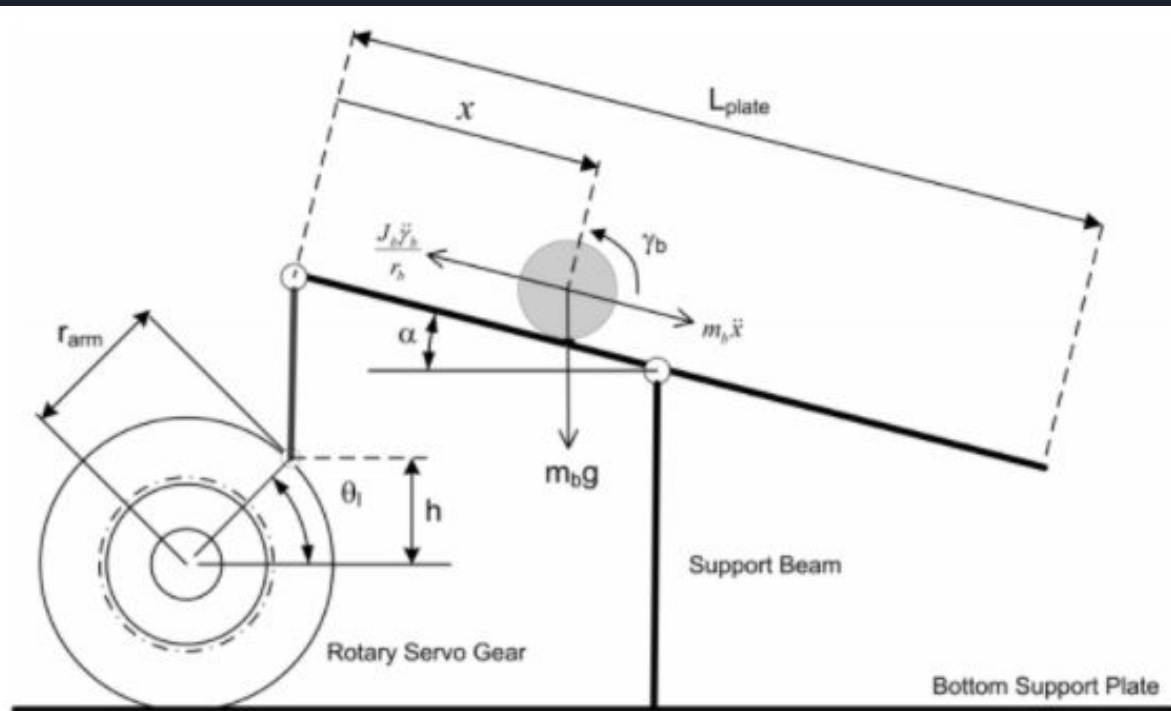


Figure 1: One dimensional model of ball on plate

Modeling

Equation 1:

$$m\ddot{x} = mg\sin(\alpha) - \frac{J\ddot{\theta}}{r^2}$$

Equation 2:

$$\sin(\alpha) = \frac{2h}{L}$$

Equation 3:

$$\sin(\theta) = \frac{h}{r_{arm}}$$

Equation 4:

$$\ddot{x}(m + \frac{J}{r^2}) = \frac{2mgr_{arm}\sin(\theta)}{L}$$

Equation 5:

$$\ddot{x}(m + (\frac{J}{r^2})) = \frac{2mgh}{L} \theta$$

Equation 6:

$$X(s)(m + (\frac{J}{r^2}))s^2 = \frac{2mgh}{L} \theta(s)$$

Equation 7:

$$\frac{X(s)}{\theta(s)} = \frac{2mgh}{(s^2L(m+(\frac{J}{r^2})))}$$

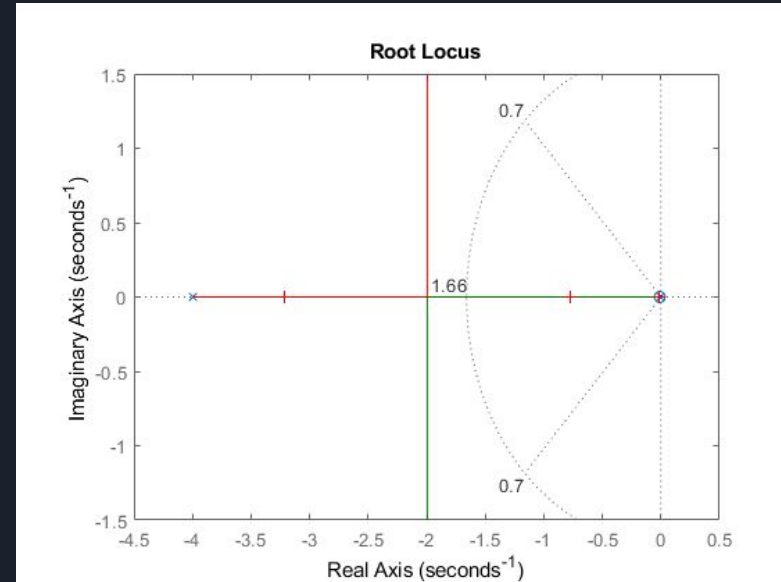
Controller Design / Root Locus

$$\%OS = 100e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}}$$

$$t_s = -\frac{\ln(c_{ts}\sqrt{1-\zeta^2})}{\zeta\omega_n}$$

$$\frac{Y(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

- Chosen parameters-
 - Settling Time: 3.5 seconds
 - Percent Overshoot: 5%
- Values Obtained-
 - Damping ratio: 0.7
 - Natural frequency: 1.66





Coppelia Code

```
1 simRemoteApi.start(19999)
2 function sysCall_init()
3     sim.handleSimulationStart()
4     sim.openModule(sim.handle_all)
5     sim.handleGraph(sim.handle_all_except_explicit,0)
6 end
7
8 function sysCall_actuation()
9     sim.resumeThreads(sim.scriptthreadresume_default)
10    sim.resumeThreads(sim.scriptthreadresume_actuation_first)
11    sim.launchThreadedChildScripts()
12    sim.handleChildScripts(sim.syscb_actuation)
13    sim.resumeThreads(sim.scriptthreadresume_actuation_last)
14    sim.handleCustomizationScripts(sim.syscb_actuation)
15    sim.handleAddOnScripts(sim.syscb_actuation)
16    sim.handleSandboxScript(sim.syscb_actuation)
17    sim.handleModule(sim.handle_all,false)
18    sim.handleIkGroup(sim.handle_all_except_explicit)
19    sim.handleDynamics(sim.getSimulationTimeStep())
20 end
21
22 function sysCall_sensing()
```



Coppelia Code

```
23     sim.handleSensingStart()
24     sim.handleCollision(sim.handle_all_except_explicit)
25     sim.handleDistance(sim.handle_all_except_explicit)
26     sim.handleProximitySensor(sim.handle_all_except_explicit)
27     sim.handleVisionSensor(sim.handle_all_except_explicit)
28     sim.resumeThreads(sim.scriptthreadresume_sensing_first)
29     sim.handleChildScripts(sim.syscb_sensing)
30     sim.resumeThreads(sim.scriptthreadresume_sensing_last)
31     sim.handleCustomizationScripts(sim.syscb_sensing)
32     sim.handleAddOnScripts(sim.syscb_sensing)
33     sim.handleSandboxScript(sim.syscb_sensing)
34     sim.handleModule(sim.handle_all,true)
35     sim.resumeThreads(sim.scriptthreadresume_allnotyetresumed)
36     sim.handleGraph(sim.handle_all_except_explicit,sim.getSimulationTime()+sim.getSimulationTimeStep())
37 end
38
39 function sysCall_cleanup()
40     sim.resetCollision(sim.handle_all_except_explicit)
41     sim.resetDistance(sim.handle_all_except_explicit)
42     sim.resetProximitySensor(sim.handle_all_except_explicit)
43     sim.resetVisionSensor(sim.handle_all_except_explicit)
44     sim.closeModule(sim.handle_all)
```



Coppelia Code

```
44     sim.closeModule(sim.handle_all)
45 end
46
47 function sysCall_suspend()
48     sim.handleChildScripts(sim.syscb_suspend)
49     sim.handleCustomizationScripts(sim.syscb_suspend)
50     sim.handleAddOnScripts(sim.syscb_suspend)
51     sim.handleSandboxScript(sim.syscb_suspend)
52 end
53
54 function sysCall_suspended()
55     sim.handleChildScripts(sim.syscb_suspended)
56     sim.handleCustomizationScripts(sim.syscb_suspended)
57     sim.handleAddOnScripts(sim.syscb_suspended)
58     sim.handleSandboxScript(sim.syscb_suspended)
59 end
60
61 function sysCall_resume()
62     sim.handleChildScripts(sim.syscb_resume)
63     sim.handleCustomizationScripts(sim.syscb_resume)
64     sim.handleAddOnScripts(sim.syscb_resume)
65     sim.handleSandboxScript(sim.syscb_resume)
66 end
67
```

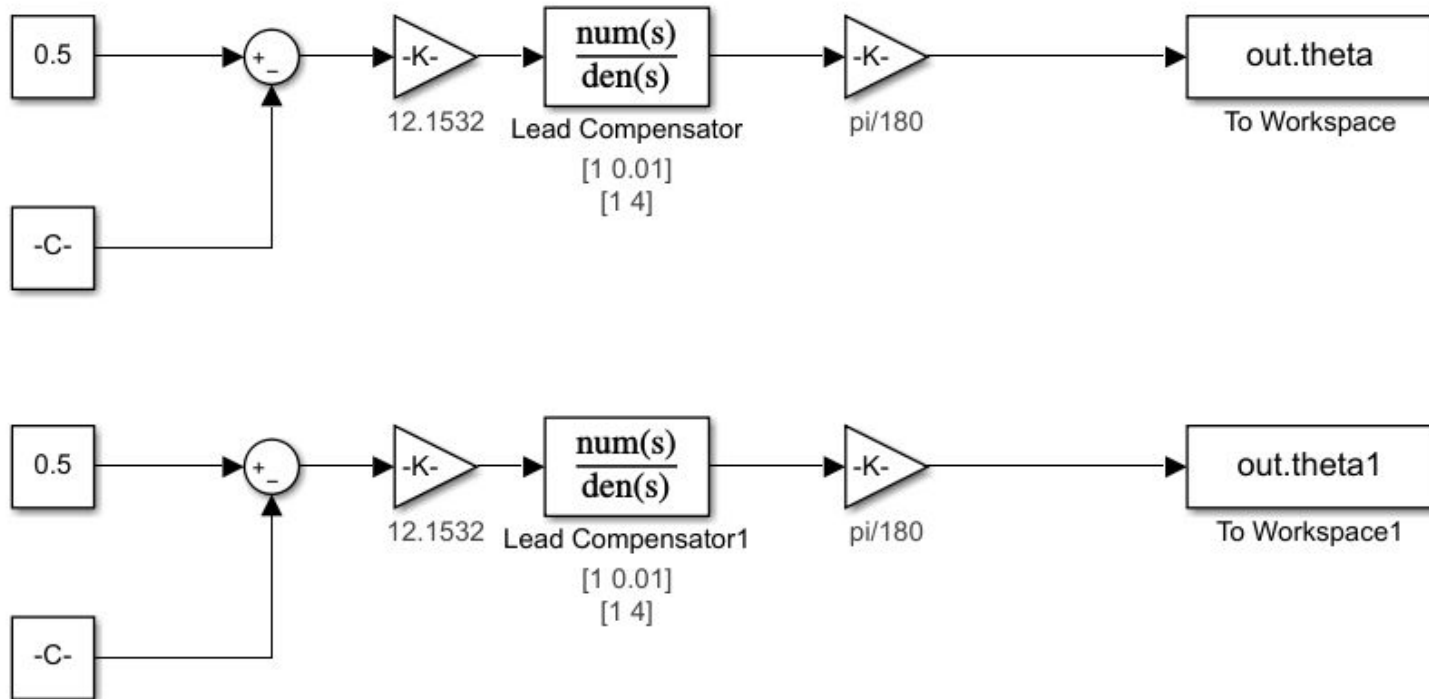

Coppelia Code

```
1 function sysCall_threadmain()
2     simRemoteApi.start(19999)
3     out=sim.auxiliaryConsoleOpen("Debug", 8, 1)
4     cam=sim.getObjectHandle("Cam")
5     while (sim.getSimulationState()~=sim.simulation_advancing_abouttostop) do
6         simVision.sensorImgToWorkImg(cam)
7         unused,pack1=simVision.blobDetectionOnWorkImg(cam, 0.1, 0, false, nil)
8         unpack1=sim.unpackFloatTable(pack1,0,0,0)
9         xcoord=unpack1[5]
10        ycoord=unpack1[6]
11        sim.auxiliaryConsolePrint(out,ycoord)
12        sim.auxiliaryConsolePrint(out," ")
13        sim.auxiliaryConsolePrint(out,xcoord)
14        sim.auxiliaryConsolePrint(out,"\n")
15        sim.setStringSignal("distance", pack1)
16    end
17 end
18
19 function CoordCalc(inInts, inFloats,inStrings,inBuffer)
20     cam1=sim.getObjectHandle("Cam")
21     simVision.sensorImgToWorkImg(cam1)
22     unused2,pack2=simVision.blobDetectionOnWorkImg(cam1, 0.1, 0, false, nil)
23     unpack2=sim.unpackFloatTable(pack2,0,0,0)
24     xcoord1=unpack1[5]
25     ycoord1=unpack1[6]
26     return {}, {xcoord1,ycoord1}, {}, ''
27
28 end
29
```

Matlab Code

```
MECA482ProjectCode.m x +
1 - clear all; close all; clc
2 - CopSim=remApi('remoteApi'); CopSim.simxFinish(-1); clientID=CopSim.simxStart('127.0.0.1',19999,true,true,5000,5);
3 - if (clientID>-1)
4 -     disp('Connected');
5 -     set_param('SystemModel','SimulationCommand','start')
6 -     h=[0,0];
7 -     [r,h(1)]=CopSim.simxGetObjectHandle(clientID, 'RotateY0',CopSim.simx_opmode_blocking);
8 -     [r,h(2)]=CopSim.simxGetObjectHandle(clientID, 'RotateX',CopSim.simx_opmode_blocking);
9 -     while true
10 -        [res,retInts,retFloats,retStrings,retBuffer]=CopSim.simxCallScriptFunction(clientID,'Cam',CopSim.sim_scripttype_childscript,'CoordCalc',[],[],[])
11 -        xc=retFloats(1); ycoord=retFloats(2);
12 -        r_x=xc;
13 -        set_param('SystemModel/Constant','Value',num2str(r_x));
14 -        pause(.01); r_y=ycoord;
15 -        set_param('SystemModel/Constant2','Value',num2str(r_y)); pause(.01);
16 -        tx=get_param('SystemModel/To Workspace','RuntimeObject');
17 -        aX= (tx.InputPort(1).Data * 10000);
18 -        ty=get_param('SystemModel/To Workspace1','RuntimeObject');
19 -        a1= (ty.InputPort(1).Data * 10000);
20 -        CopSim.simxSetJointTargetPosition(clientID,h(2),aX,CopSim.simx_opmode_streaming)
21 -        CopSim.simxSetJointTargetPosition(clientID,h(1),a1,CopSim.simx_opmode_streaming)
22 -    end
23 - else
24 -     disp('Failed to connect to remote API');
25 - end
26 - CopSim.delete();
```

Simulink Model



Coppelia Simulation

