Design Project: Inertia Pendulum
SP21 MECA-482
5/23/2021

Project Team:

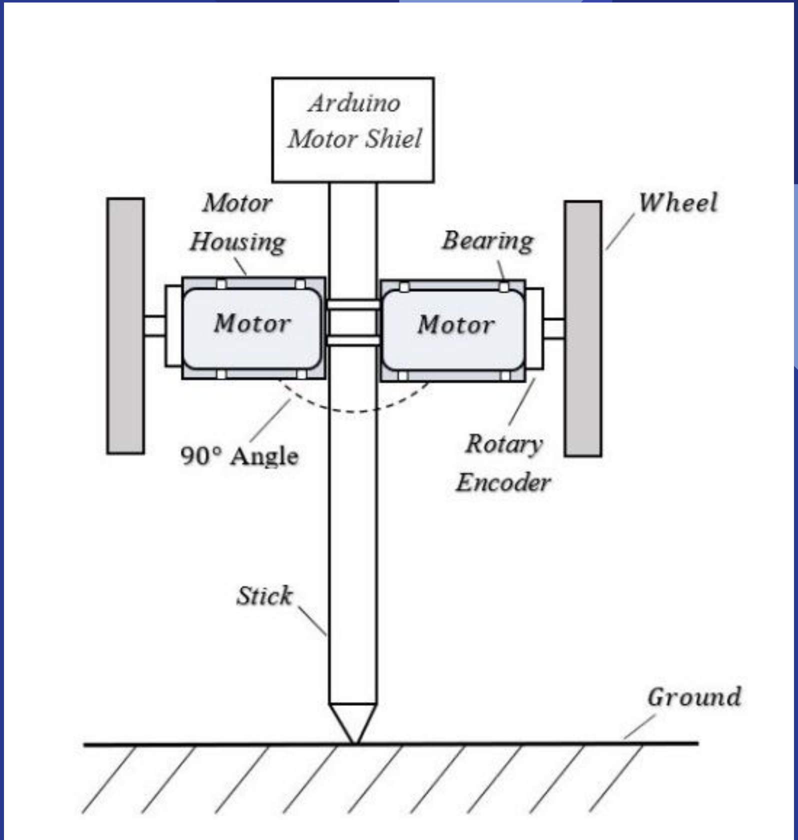
- Bailey Burja
- Phinease Francis
- Kevin Seaman
- Cher Thor

Hasan Sinan Bank

- Assistant Professor of Advanced Manufacturing
- M.S Mechanical Engineering 2010
- M.S Mechanical and Aerospace Engineering 2015

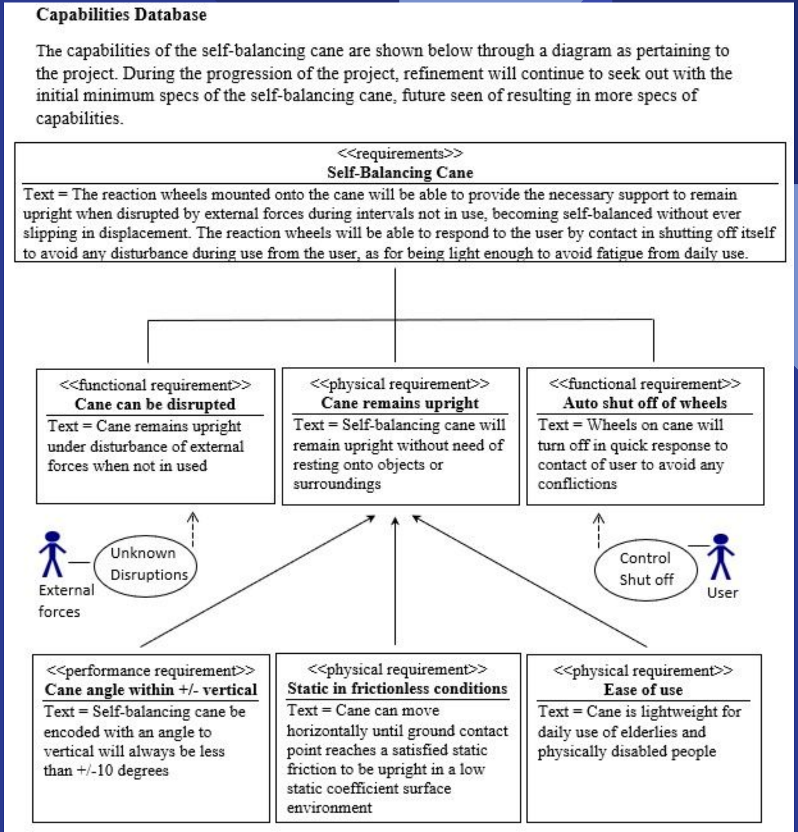
Introduction

- Elderly individuals often use a cane to help maintain balance when walking
- Cane frequently fall onto the ground
- The goal is to create a device that maintains a stable vertical orientation by using a dual axis reaction wheel set up.
- Able to counteract an external force will balance the cane to replicate disturbances onto the cane behaving like a pendulum.
- 2DOF, 1 DOF pendulum and 1 DOF for the cane



Capabilities Database

- Can be disrupted
- Cane remains upright
- Although remains upright, it can be upright within +/-10 degrees to verify specs



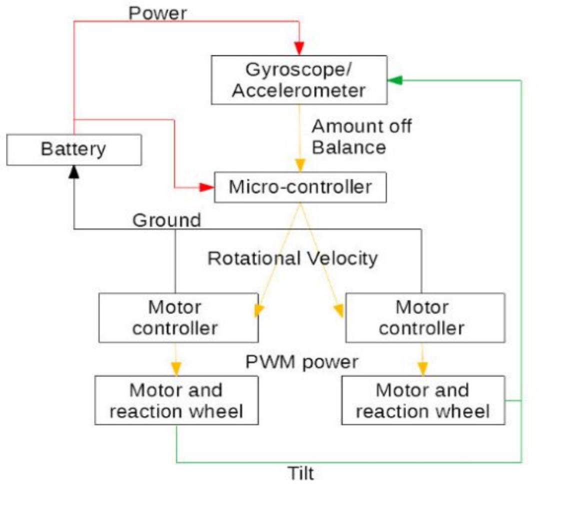
Capabilities Database

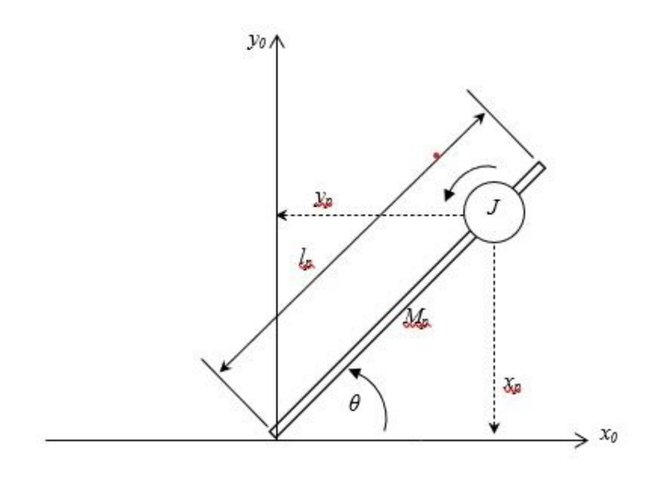
The capabilities of the self-balancing cane are shown below through a diagram as pertaining to the project. During the progression of the project, refinement will continue to seek out with the initial minimum specs of the self-balancing cane, future seen of resulting in more specs of capabilities.

System Model

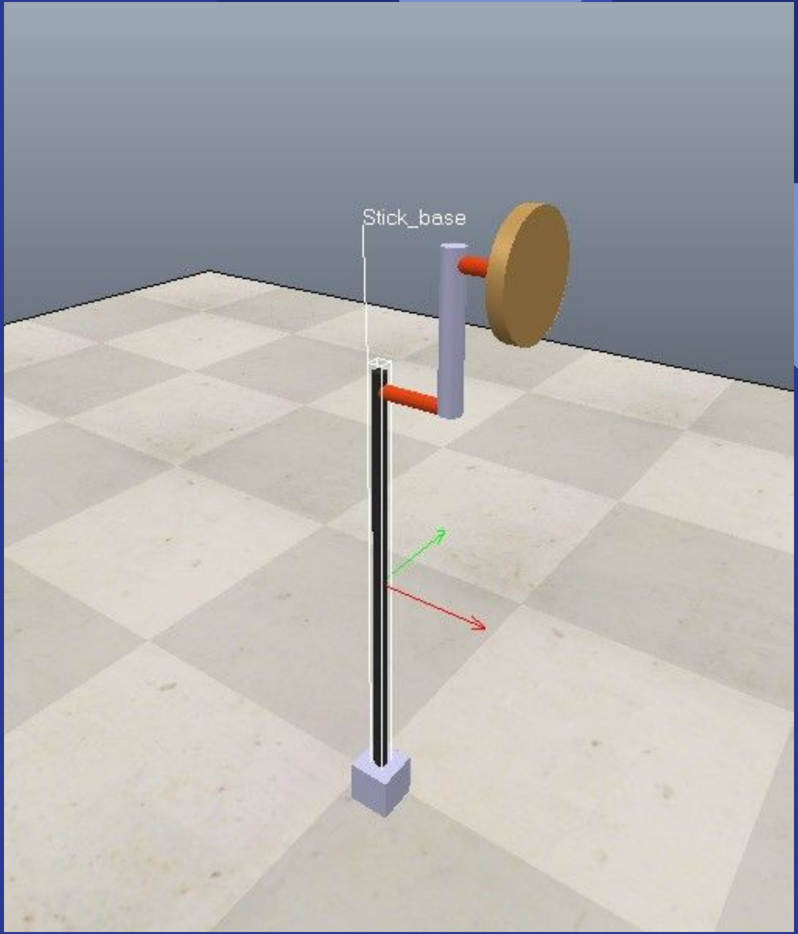
- Sensors will be negligible
- x_0 = x-axis
- xp = pendulum's position relative to the x-axis
- y_0 =y-axis
- yp = pendulum's position relative to the y-axis
- Mp = mass of pendulum
- lp= length of pendulum(cane)

$$\dot{z} = \begin{bmatrix} 0 & 1 & 0 \\ \bar{d}_{11}\bar{m}g & 0 & 0 \\ \bar{d}_{21}\bar{m}g & 0 & 0 \end{bmatrix} z + \begin{bmatrix} 0 \\ \bar{d}_{12} \\ \bar{d}_{22} \end{bmatrix} \tau$$





Controller Design & Simulation



MATLAB Code

Closed Loop Model:

```
clc; clear; close all;

% Motor parameters (from vendor or references

R=4.172;

km = 0.00775;

Umax = 13;


% Inertial wheel model

g = 9.81; % Gravitational acceleration

mgl = 0.12597;

mbg = mgl;

d11 = 0.0014636;

d12 = 0.0000076;

d21 = d12;

d22 = d21;
```

```
di11 = Di(1,1);
di12 = Di(1,2);
di21 = Di(2,1);
di22 = Di(2,2);

% Linear approximate model of IWP
A = [ 0 1 0; di11*mbg 0 0; di21*mbg 0 0];
B = [0; di12*km/R; di22*km/R];

%System parameters
C = eye(size(A));

%No need to define D
D = (0);


% Controllability for making sure of the application of
% full-state feedback
disp('Is the system controllable?');
Pc = ctrb(A,B);
if rank(Pc) == size(Pc)
   disp('Yes.');
else
   disp('No.');
end

% Desired closed-loop eigenvalues (from requirements)
s1 = -9.27 + 20.6i;
s2 = -9.27 - 20.6i;
s3 = -0.719;
Vp = [ s1, s2, s3];
K = place(A, B, Vp);

% Verify closed-loop eigenvalues of A_new or A_cl
Vp_ = eig(A-B*K);
```

Conclusion

- The control system verifies the balance of the cane in the behavior of a pendulum with 2 DOF
- Lacks the complete controls and hardwares to successfully implement the design of the cane but has the potential to upgrade and compensate what it lacks (sensor wise and such)

References

[1] V. M. Hernandez-Guzman and R. Silva-Ortigoza, Automatic Control with Experiments, Springer, 2019

[2] Control Tutorials for MATLAB and SIMULINK - Inverted Pendulum

[3] M. W. Spong, P. Corke, and R. Lozano, Nonlinear control of the reaction wheel pendulum,Automatica, vol. 37, no. 11, pp. 1845–1851, 2001

https://github.com/bmburja/RW-V0/blob/main/README.md