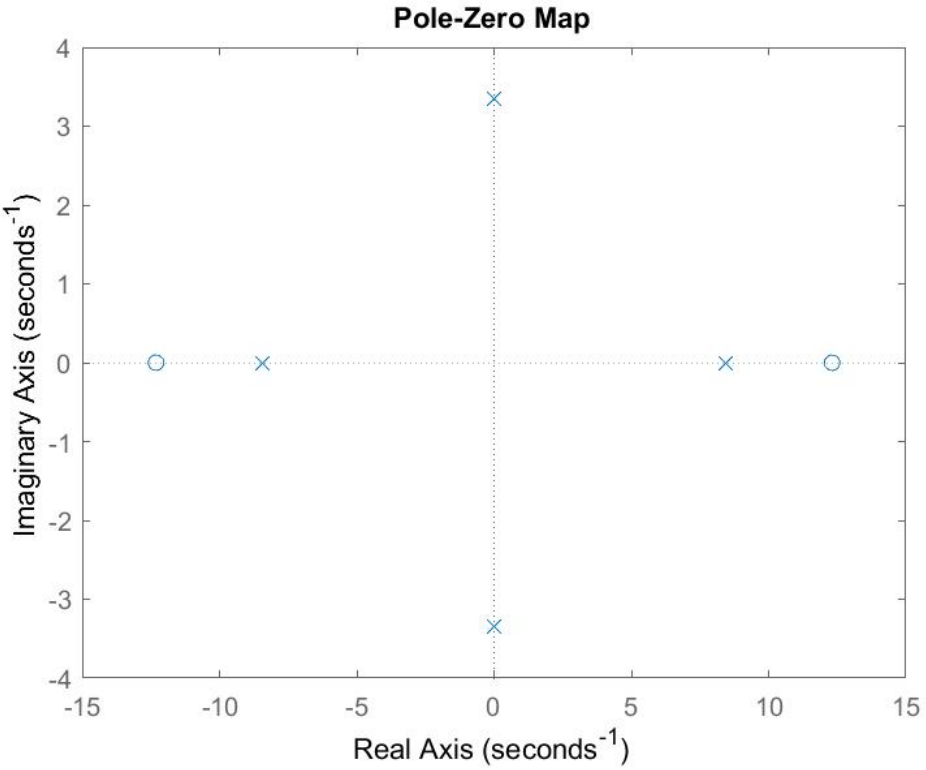
Dominic Riccoboni

From: Zachary Nathan Richter
Sent: Sunday, February 14, 2021 12:30 PM
To: Charlie Thomas Refvem
Cc: Dominic Riccoboni
Subject: Re: Linearized EOM for ball balancer

Charlie,
I subbed in the values you provided from your table and this is the pzmap I got for the dynamic system I created from my linearized A and B matrices.



There are two overlapping poles at each pole location which are at +/- 3.34 i and +/- 8.41 which from inspection does appear pretty close to the values on the plot you sent. Also a few notes, I used an I_zz inertia value of 0 since that isn't something your model considers, and I don't have a value for it. Also, my model inputs for this are still torques about the u-joint and, and not motor torque transmitted through the lever arm and push rod.

I am still thinking about what the implication of the four zeros in my system are (two at each circle marker) as thinking about where zeros come from in a state space model isn't something I am familiar with.

Thanks,
Zach

From: Zachary Nathan Richter <zrichter@calpoly.edu>
Sent: Saturday, February 13, 2021 9:48 PM
To: Charlie Thomas Refvem <crefvem@calpoly.edu>

Cc: Dominic Riccoboni <driccobo@calpoly.edu>
Subject: Re: Linearized EOM for ball balancer

Attached are Murray's hand calcs

Also yes I have the same sort of open loop pole locations. I just have two poles on each axis direction (positive and negative) for a total of 8 poles.

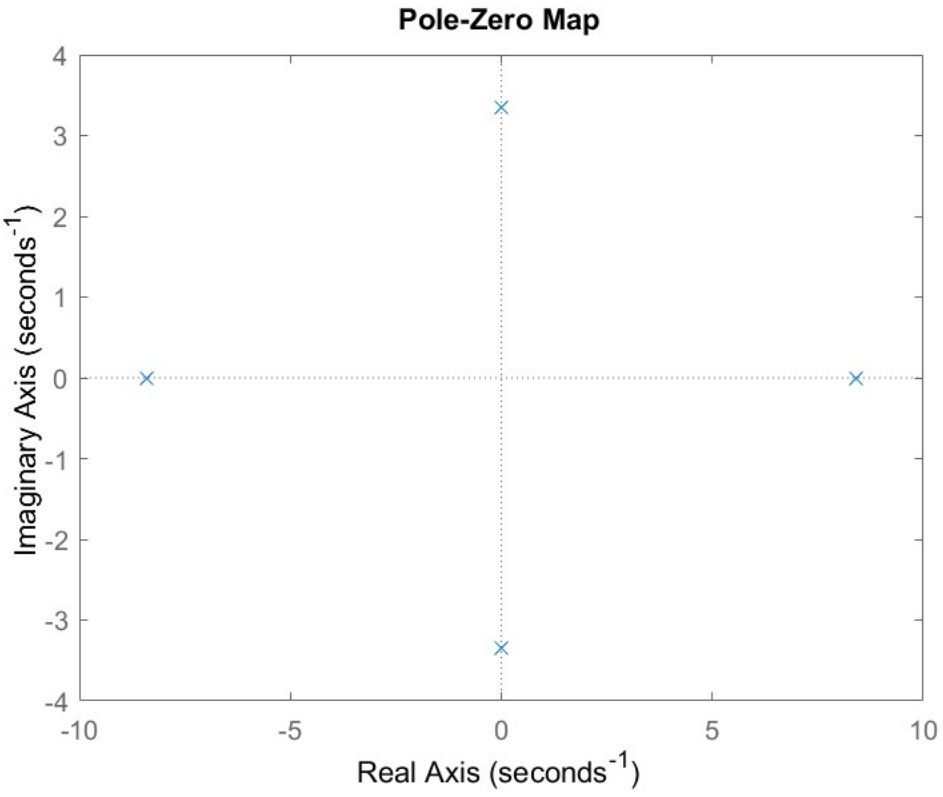
I will check the numerical values tomorrow.

Best,
Zach

From: Charlie Thomas Refvem <crefvem@calpoly.edu>
Sent: Saturday, February 13, 2021 9:36 PM
To: Zachary Nathan Richter <zrichter@calpoly.edu>
Cc: Dominic Riccoboni <driccobo@calpoly.edu>
Subject: RE: Linearized EOM for ball balancer

Hmm… this will be challenging. How about we compare pole locations? My 4 poles should match 4 out of 8 of your poles for the open loop system. Can you confirm for me if you have the same "sort" of poles without changing anything? If you could, tell me that and then if you have a chance plug in my parameters and give me your numerical values later.

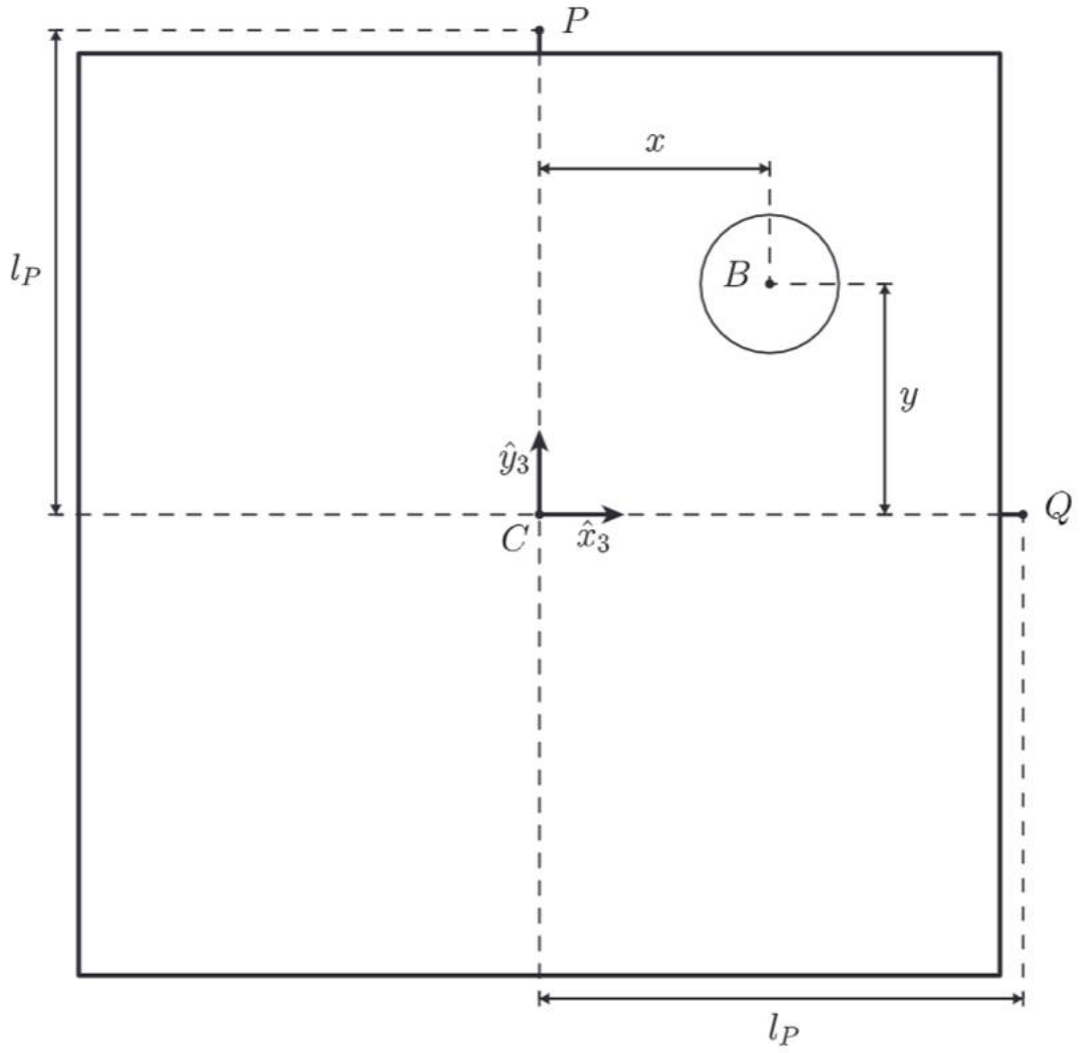
Here are my pole locations:

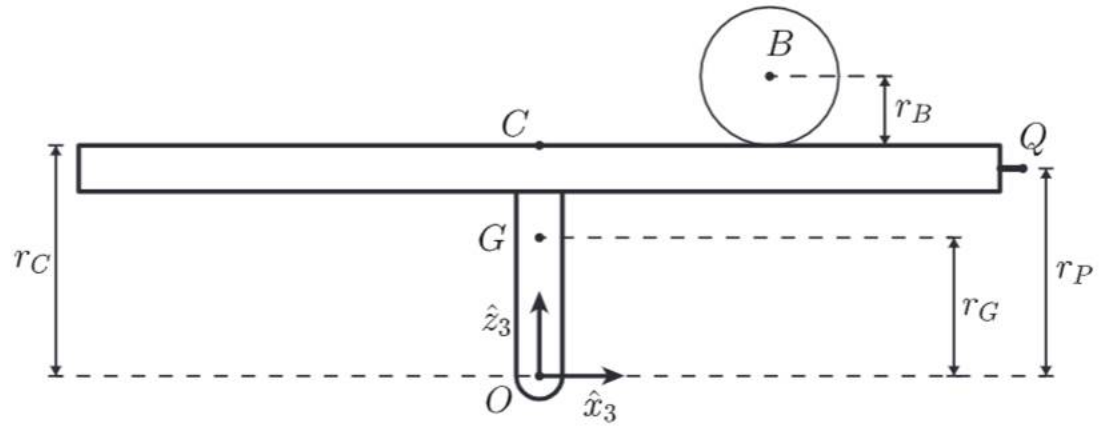


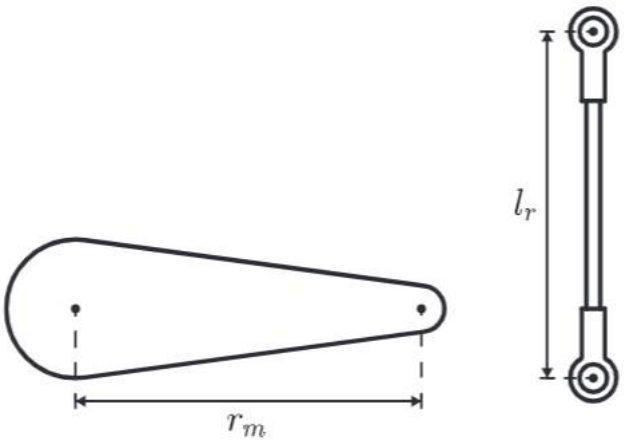
Here are the parameters that I'm using:

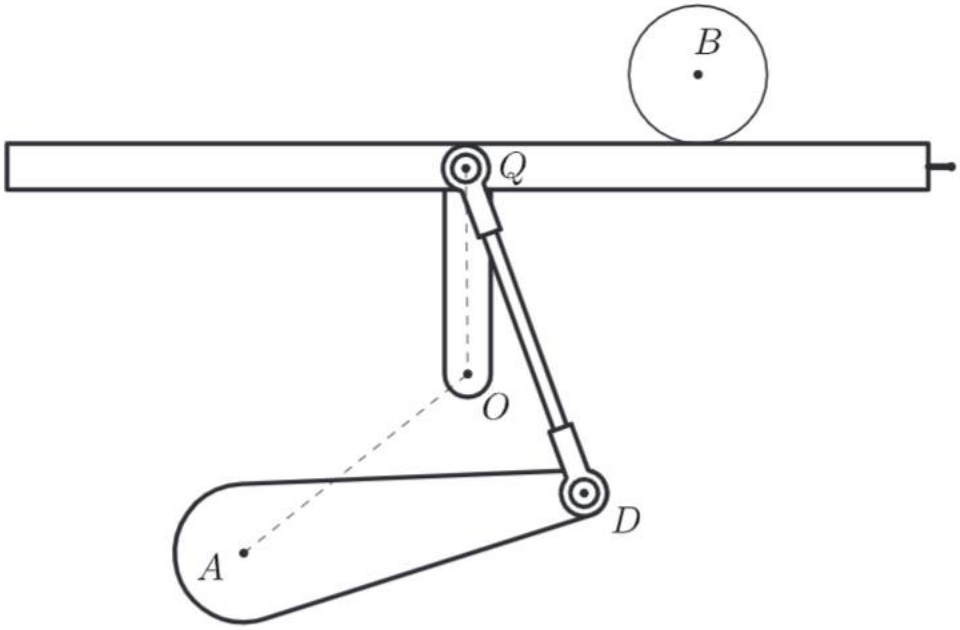
Radius of Lever Arm	r_m	$60\ [mm]$
Length of Push Rod	l_r	$50\ [mm]$
Radius of Ball	r_B	$10.5\ [mm]$
Vertical Distance from U-Joint to CG of Platform	r_G	$42\ [mm]$
Horizontal Distance from U-Joint to Push-Rod Pivot	l_P	$110\ [mm]$
Vertical Distance from U-Joint to Push-Rod Pivot	r_P	$32.5\ [mm]$
Vertical Distance from U-Joint to Platform Surface	r_C	$50\ [mm]$
Mass of Ball	m_B	$30\ [g]$
Mass of Platform	m_P	$400\ [g]$
Moment of Inertia of Platform (About Horizontal Axis through CG)	I_P	$1.88 \times 10^6\ [g \cdot mm^2]$

Which go with the following figures:


P
x
B
l_P
y
$\hat{y}_3$
C
$\hat{x}_3$
Q
l_P


B
r_B
C
Q
G
r_C
r_G
r_P
$\hat{z}_3$
O
$\hat{x}_3$





If you have them around send me the equations Bill sent you a while back.

Thanks,
Charlie

From: Zachary Nathan Richter <zrichter@calpoly.edu>
Sent: Saturday, February 13, 2021 9:28 PM
To: Charlie Thomas Refvem <crefvem@calpoly.edu>
Cc: Dominic Riccoboni <driccobo@calpoly.edu>
Subject: Re: Linearized EOM for ball balancer

Charlie,

Everything that I have symbolically will have the coupled terms and be non-linear. Linearizing the long equations symbolically isn't something I have let MATLAB finish running through as it took a very long time. I'd be happy to take a look at them and see what similarities there are.

Also, Dr. Murray sent me some of his non-linear ball and beam equations a while back. If you haven't seen those, I could send them and see if yours are the linearized version of those equations.

Let me know,
Zach

From: Charlie Thomas Refvem <crefvem@calpoly.edu>
Sent: Saturday, February 13, 2021 8:39 PM
To: Zachary Nathan Richter <zrichter@calpoly.edu>
Cc: Dominic Riccoboni <driccobo@calpoly.edu>
Subject: Linearized EOM for ball balancer

Zach,

I'm working on a simplified model of the ball balancer using a decoupled "two balance beams" approximation. I've got some equations I would like to confirm. I was wondering if you had anything already available in a form that was "easy enough" to share. There are a couple things we could do to compare. Some will be easier if we have the same notation, and others will be easier if we have the same numerical values.

Thanks,

Charlie