MEAM 520

From Simulation to Reality

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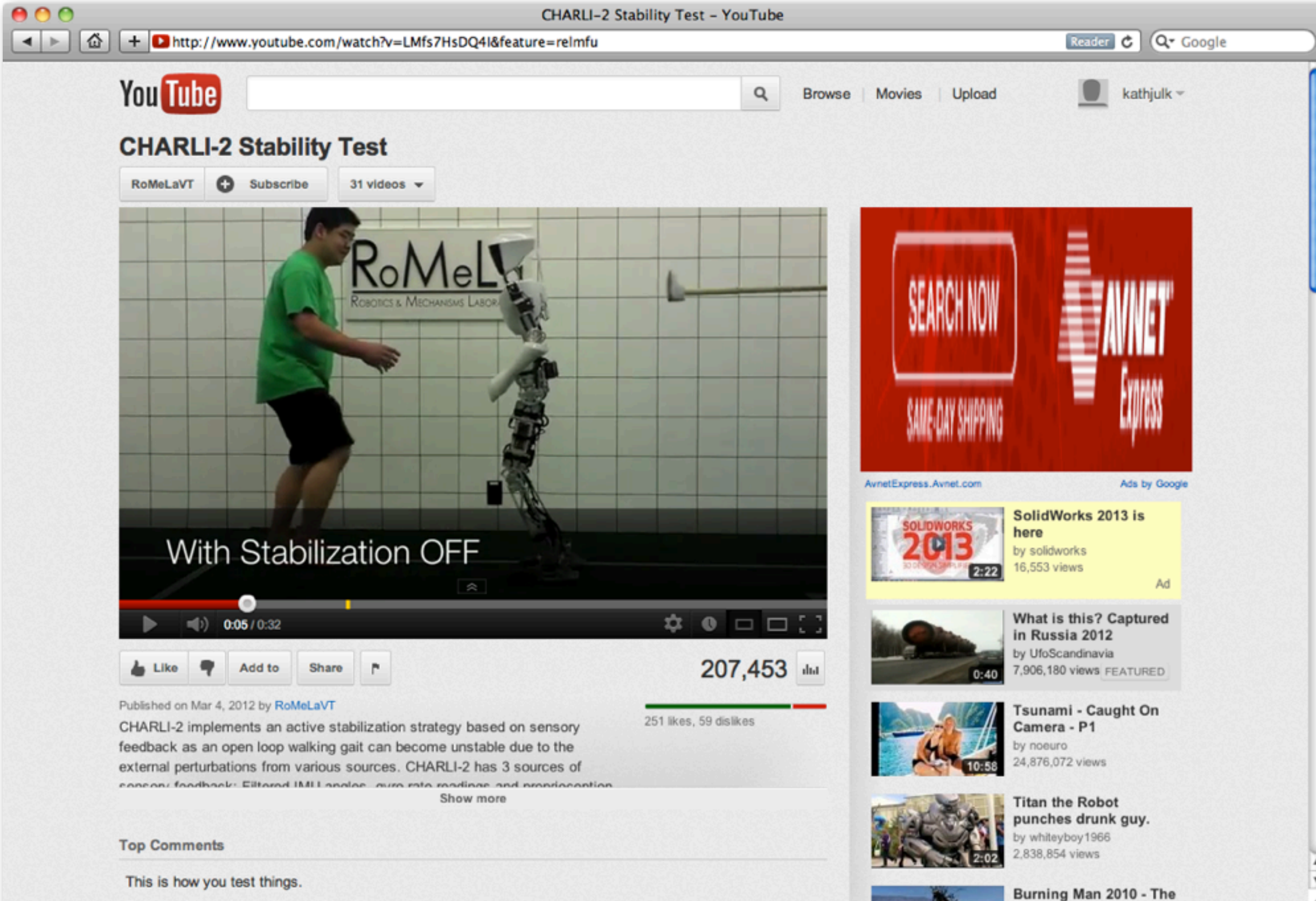
General Robotics, Automation, Sensing, and Perception Lab (GRASP)
MEAM Department, SEAS, University of Pennsylvania

Lecture 13: October 25, 2012


CHARLI-2 Stability Test - YouTube
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Published on Mar 4, 2012 by RoMeLaVT
CHARLI-2 implements an active stabilization strategy based on sensory
feedback as an open loop walking gait can become unstable due to the
external perturbations from various sources. CHARLI-2 has 3 sources of
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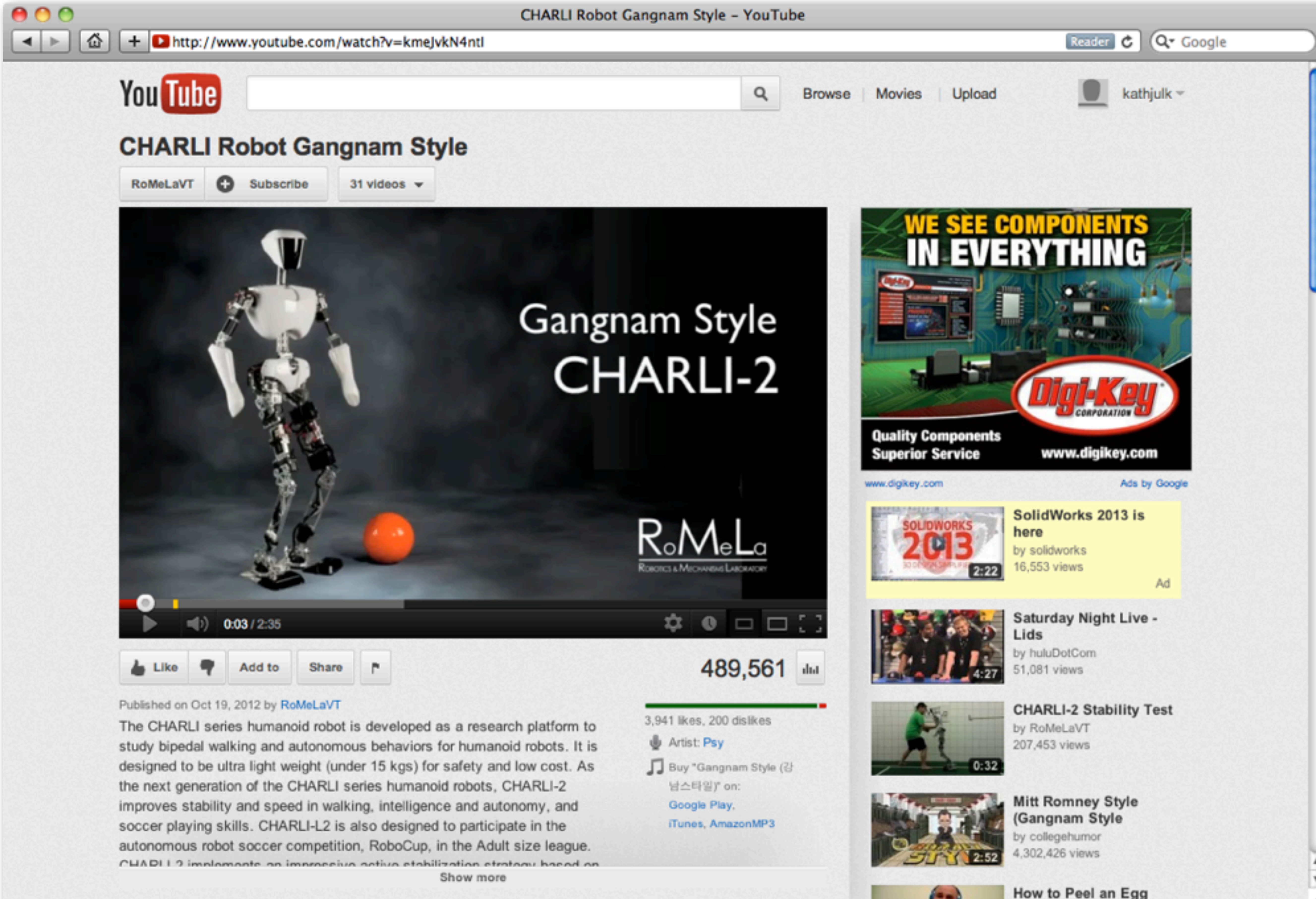
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0:03 / 2:35
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Published on Oct 19, 2012 by RoMeLaVT
The CHARLI series humanoid robot is developed as a research platform to study bipedal walking and autonomous behaviors for humanoid robots. It is designed to be ultra light weight (under 15 kgs) for safety and low cost. As the next generation of the CHARLI series humanoid robots, CHARLI-2 improves stability and speed in walking, intelligence and autonomy, and soccer playing skills. CHARLI-L2 is also designed to participate in the autonomous robot soccer competition, RoboCup, in the Adult size league.
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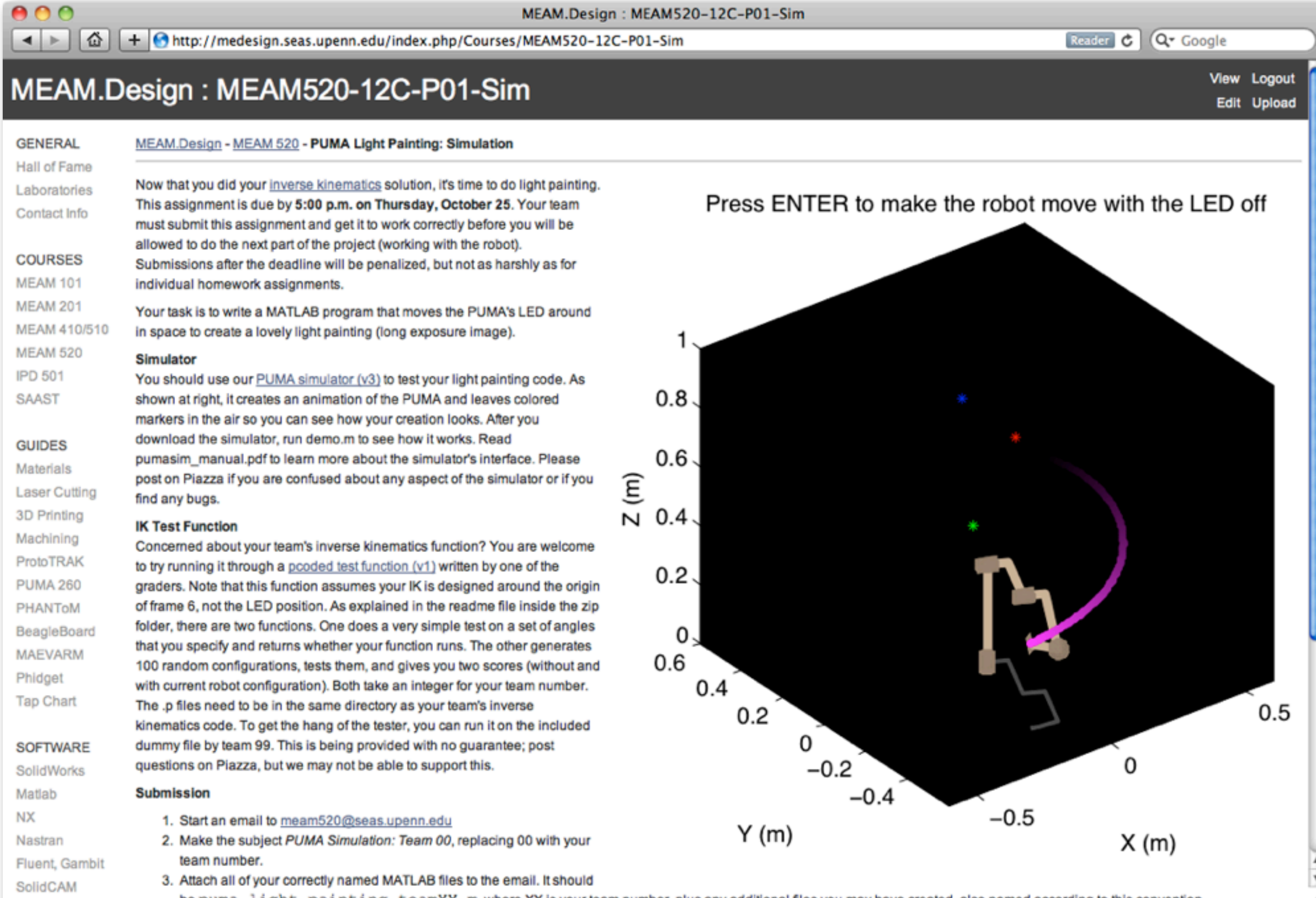
How to Peel an Egg

How do you think CHARLI-2
was taught to dance Gangnam Style?

Project 1 : PUMA Light Painting



MEAM.Design : MEAM520-12C-P01-Sim

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SolidCAM

MEAM.Design - MEAM 520 - **PUMA Light Painting: Simulation**

Now that you did your inverse kinematics solution, it's time to do light painting. This assignment is due by **5:00 p.m. on Thursday, October 25**. Your team must submit this assignment and get it to work correctly before you will be allowed to do the next part of the project (working with the robot). Submissions after the deadline will be penalized, but not as harshly as for individual homework assignments.

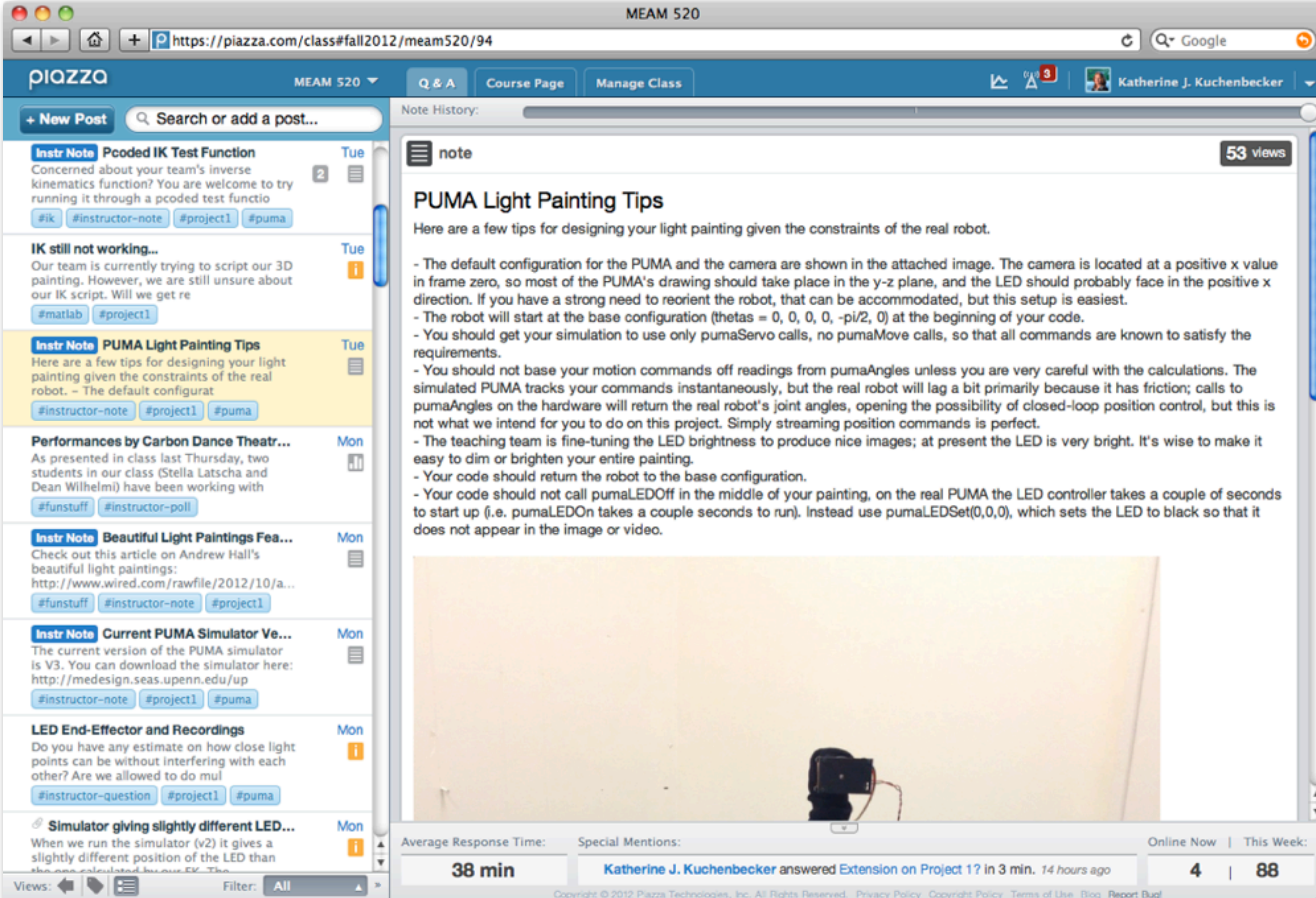
Your task is to write a MATLAB program that moves the PUMA's LED around in space to create a lovely light painting (long exposure image).

Simulator
You should use our PUMA simulator (v3) to test your light painting code. As shown at right, it creates an animation of the PUMA and leaves colored markers in the air so you can see how your creation looks. After you download the simulator, run demo.m to see how it works. Read pumasim_manual.pdf to learn more about the simulator's interface. Please post on Piazza if you are confused about any aspect of the simulator or if you find any bugs.

IK Test Function
Concerned about your team's inverse kinematics function? You are welcome to try running it through a pcoded test function (v1) written by one of the graders. Note that this function assumes your IK is designed around the origin of frame 6, not the LED position. As explained in the readme file inside the zip folder, there are two functions. One does a very simple test on a set of angles that you specify and returns whether your function runs. The other generates 100 random configurations, tests them, and gives you two scores (without and with current robot configuration). Both take an integer for your team number. The .p files need to be in the same directory as your team's inverse kinematics code. To get the hang of the tester, you can run it on the included dummy file by team 99. This is being provided with no guarantee; post questions on Piazza, but we may not be able to support this.

Submission

1. Start an email to meam520@seas.upenn.edu
2. Make the subject *PUMA Simulation: Team 00*, replacing 00 with your team number.
3. Attach all of your correctly named MATLAB files to the email. It should be puma_light_painting_teamXX.m where XX is your team number, plus any additional files you may have created, also named according to this convention.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Note History:
Instr Note Pcoded IK Test Function
Tue
Concerned about your team's inverse kinematics function? You are welcome to try running it through a pcoded test functio
2
#ik #instructor-note #project1 #puma
IK still not working...
Tue
Our team is currently trying to script our 3D painting. However, we are still unsure about our IK script. Will we get re
#matlab #project1
Instr Note PUMA Light Painting Tips
Tue
Here are a few tips for designing your light painting given the constraints of the real robot. - The default configurat
#instructor-note #project1 #puma
Performances by Carbon Dance Theatr...
Mon
As presented in class last Thursday, two students in our class (Stella Latscha and Dean Wilhelmi) have been working with
#funstuff #instructor-poll
Instr Note Beautiful Light Paintings Fea...
Mon
Check out this article on Andrew Hall's beautiful light paintings: http://www.wired.com/rawfile/2012/10/a...
#funstuff #instructor-note #project1
Instr Note Current PUMA Simulator Ve...
Mon
The current version of the PUMA simulator is V3. You can download the simulator here: http://medesign.seas.upenn.edu/up
#instructor-note #project1 #puma
LED End-Effector and Recordings
Mon
Do you have any estimate on how close light points can be without interfering with each other? Are we allowed to do mul
#instructor-question #project1 #puma
Simulator giving slightly different LED...
Mon
When we run the simulator (v2) it gives a slightly different position of the LED than
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53 views
PUMA Light Painting Tips
Here are a few tips for designing your light painting given the constraints of the real robot.
- The default configuration for the PUMA and the camera are shown in the attached image. The camera is located at a positive x value in frame zero, so most of the PUMA's drawing should take place in the y-z plane, and the LED should probably face in the positive x direction. If you have a strong need to reorient the robot, that can be accommodated, but this setup is easiest.
- The robot will start at the base configuration (thetas = 0, 0, 0, 0, -pi/2, 0) at the beginning of your code.
- You should get your simulation to use only pumaServo calls, no pumaMove calls, so that all commands are known to satisfy the requirements.
- You should not base your motion commands off readings from pumaAngles unless you are very careful with the calculations. The simulated PUMA tracks your commands instantaneously, but the real robot will lag a bit primarily because it has friction; calls to pumaAngles on the hardware will return the real robot's joint angles, opening the possibility of closed-loop position control, but this is not what we intend for you to do on this project. Simply streaming position commands is perfect.
- The teaching team is fine-tuning the LED brightness to produce nice images; at present the LED is very bright. It's wise to make it easy to dim or brighten your entire painting.
- Your code should return the robot to the base configuration.
- Your code should not call pumaLEDOff in the middle of your painting, on the real PUMA the LED controller takes a couple of seconds to start up (i.e. pumaLEDOn takes a couple seconds to run). Instead use pumaLEDSet(0,0,0), which sets the LED to black so that it does not appear in the image or video.
Average Response Time:
38 min
Special Mentions:
Katherine J. Kuchenbecker answered Extension on Project 1? in 3 min. 14 hours ago
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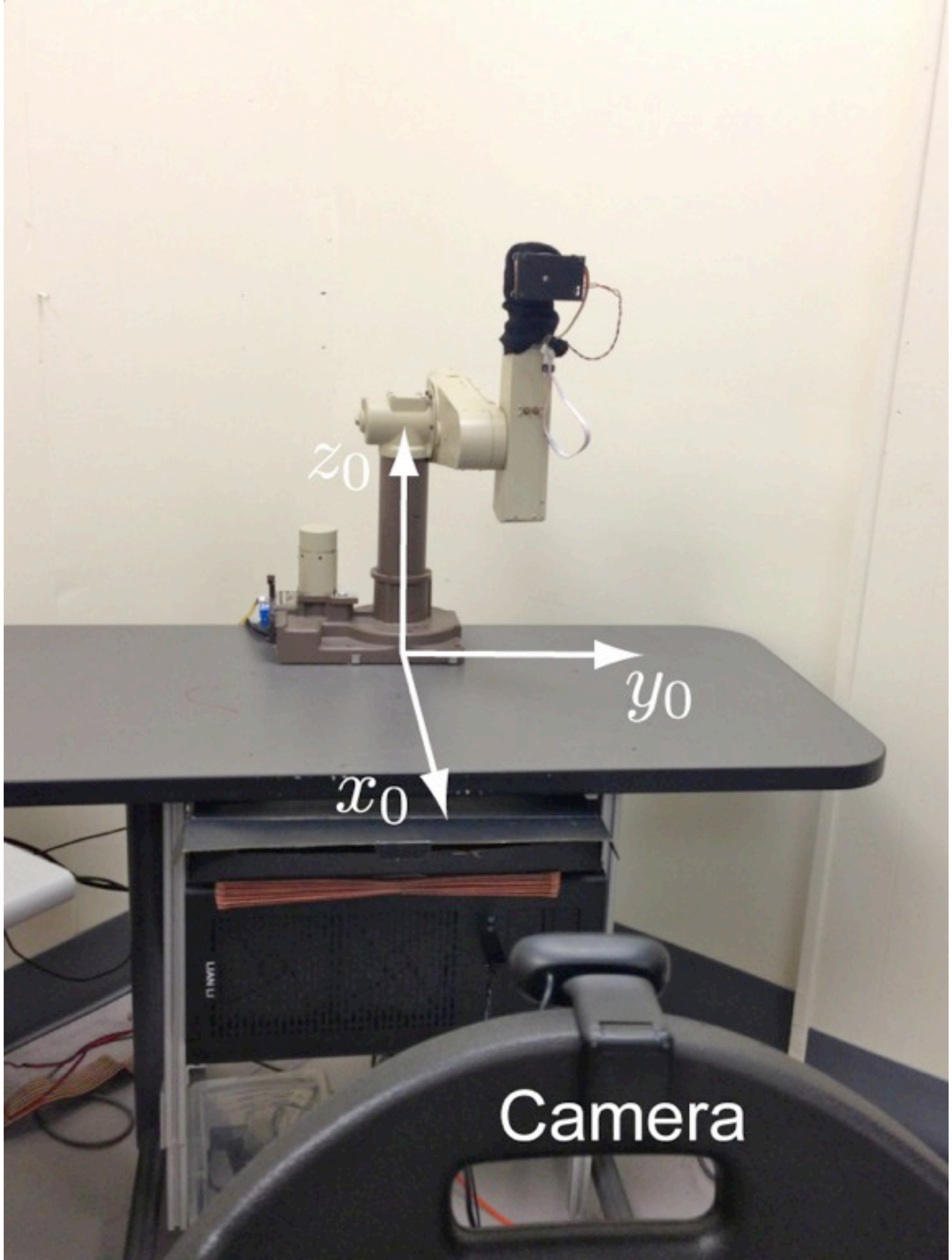

z_0
y_0
x_0
Camera

Your team needs to turn in a light painting simulation.

This is ostensibly due today, and I know you've been working hard on it.

If you submit something incomplete, you will need to fix it before you work on the real robot.

Even if you think your simulation is perfect, there will probably be some small things to update.

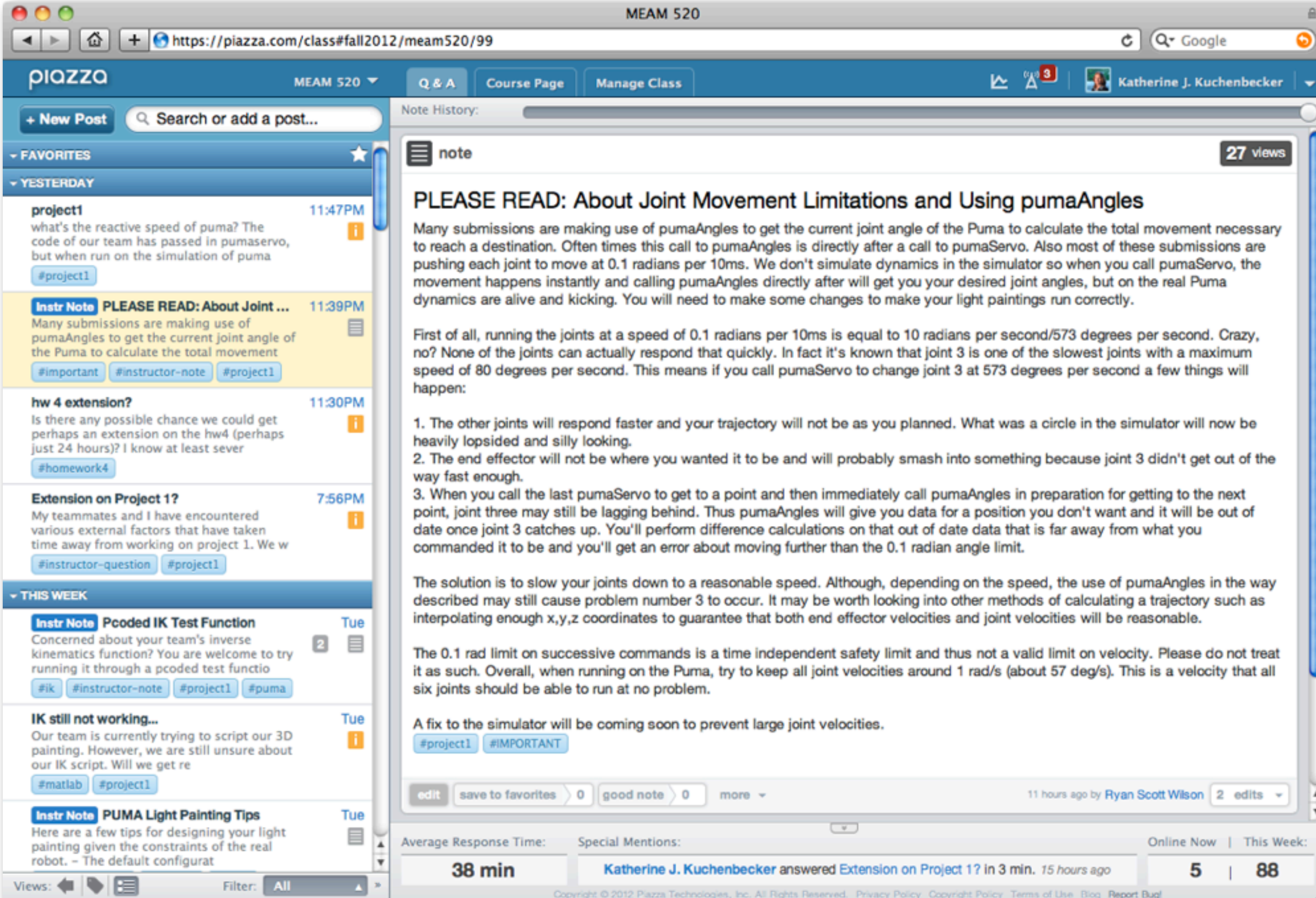
Work hard, but don't freak out about the deadline. Figure out the issues and get your submission in when you can. Post, email, or come to office hours for help.

Checking the code of the teams who have submitted already revealed an important bug in the simulator.

The joint velocity check is not being done correctly, so you can command very high joint velocities.

1 radian per second is the maximum joint velocity you should ever be using.

We are working to release V4 of the simulator where this bug is patched, but svn server is down...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FAVORITES
YESTERDAY
project1
11:47PM
what's the reactive speed of puma? The code of our team has passed in pumaservo, but when run on the simulation of puma
#project1
Instr Note PLEASE READ: About Joint ...
11:39PM
Many submissions are making use of pumaAngles to get the current joint angle of the Puma to calculate the total movement
#important #instructor-note #project1
hw 4 extension?
11:30PM
Is there any possible chance we could get perhaps an extension on the hw4 (perhaps just 24 hours)? I know at least sever
#homework4
Extension on Project 1?
7:56PM
My teammates and I have encountered various external factors that have taken time away from working on project 1. We w
#instructor-question #project1
THIS WEEK
Instr Note Pcoded IK Test Function
Tue
Concerned about your team's inverse kinematics function? You are welcome to try running it through a pcoded test functio
#ik #instructor-note #project1 #puma
IK still not working...
Tue
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#matlab #project1
Instr Note PUMA Light Painting Tips
Tue
Here are a few tips for designing your light painting given the constraints of the real robot. - The default configurat
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PLEASE READ: About Joint Movement Limitations and Using pumaAngles
Many submissions are making use of pumaAngles to get the current joint angle of the Puma to calculate the total movement necessary to reach a destination. Often times this call to pumaAngles is directly after a call to pumaServo. Also most of these submissions are pushing each joint to move at 0.1 radians per 10ms. We don't simulate dynamics in the simulator so when you call pumaServo, the movement happens instantly and calling pumaAngles directly after will get you your desired joint angles, but on the real Puma dynamics are alive and kicking. You will need to make some changes to make your light paintings run correctly.
First of all, running the joints at a speed of 0.1 radians per 10ms is equal to 10 radians per second/573 degrees per second. Crazy, no? None of the joints can actually respond that quickly. In fact it's known that joint 3 is one of the slowest joints with a maximum speed of 80 degrees per second. This means if you call pumaServo to change joint 3 at 573 degrees per second a few things will happen:
1. The other joints will respond faster and your trajectory will not be as you planned. What was a circle in the simulator will now be heavily lopsided and silly looking.
2. The end effector will not be where you wanted it to be and will probably smash into something because joint 3 didn't get out of the way fast enough.
3. When you call the last pumaServo to get to a point and then immediately call pumaAngles in preparation for getting to the next point, joint three may still be lagging behind. Thus pumaAngles will give you data for a position you don't want and it will be out of date once joint 3 catches up. You'll perform difference calculations on that out of date data that is far away from what you commanded it to be and you'll get an error about moving further than the 0.1 radian angle limit.
The solution is to slow your joints down to a reasonable speed. Although, depending on the speed, the use of pumaAngles in the way described may still cause problem number 3 to occur. It may be worth looking into other methods of calculating a trajectory such as interpolating enough x,y,z coordinates to guarantee that both end effector velocities and joint velocities will be reasonable.
The 0.1 rad limit on successive commands is a time independent safety limit and thus not a valid limit on velocity. Please do not treat it as such. Overall, when running on the Puma, try to keep all joint velocities around 1 rad/s (about 57 deg/s). This is a velocity that all six joints should be able to run at no problem.
A fix to the simulator will be coming soon to prevent large joint velocities.
#project1 #IMPORTANT
edit
save to favorites 0
good note 0
more
11 hours ago by Ryan Scott Wilson
2 edits
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38 min
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Katherine J. Kuchenbecker answered Extension on Project 1? in 3 min. 15 hours ago
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How is the light painting simulation going?

What challenges are you encountering?

After you submit your simulation, one of the TAs will check it and respond with suggestions.

When your team has something ready to run, you will need to meet with your TA to get trained on the robot.

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Phidget
Tap Chart

SOFTWARE
SolidWorks
Matlab
NX
Nastran
Fluent, Gambit
SolidCAM

Calendar

	Date	Topic (Linked to Lecture Slides)	Reading	Assignments Due	Project Deadlines
01	Thu, 9/6	Course Logistics and Motivation			
02	Tue, 9/11	Rotation Matrices	B.1, 2.1-2.3		
03	Thu, 9/13	Homogenous Transformations	2.4-2.8		
04	Tue, 9/18	Manipulator Kinematics	1.1-1.3, 3.1	HW01 (Flying Box)	
05	Thu, 9/20	Denavit-Hartenberg (DH)	3.2		
06	Tue, 9/25	More Denavit-Hartenberg (DH)	3.2		
07	Thu, 9/27	Inverse Kinematics (IK)	3.3	HW02 (SCARA Robot)	
08	Tue, 10/2	More Inverse Kinematics (IK)	3.3		
09	Thu, 10/4	PUMA 260 and Project 1			
10	Tue, 10/9	More Manipulator Kinematics	3.3	HW03 (PUMA FK + SCARA IK)	PUMA Light Painting: Teams
11	Thu, 10/11	No lecture - project work time			
12	Tue, 10/16	Velocity Kinematics	4.6		PUMA Light Painting: IK
13	Thu, 10/18	More Velocity Kinematics	4.6, 4.9, 4.11, 4.12		
12	Tue, 10/23	No lecture - fall break			
13	Thu, 10/25	Real Robots			PUMA Light Painting: Simulation
14	Tue, 10/30				
15	Thu, 11/1			HW04 (Jacobians) *due Friday*	

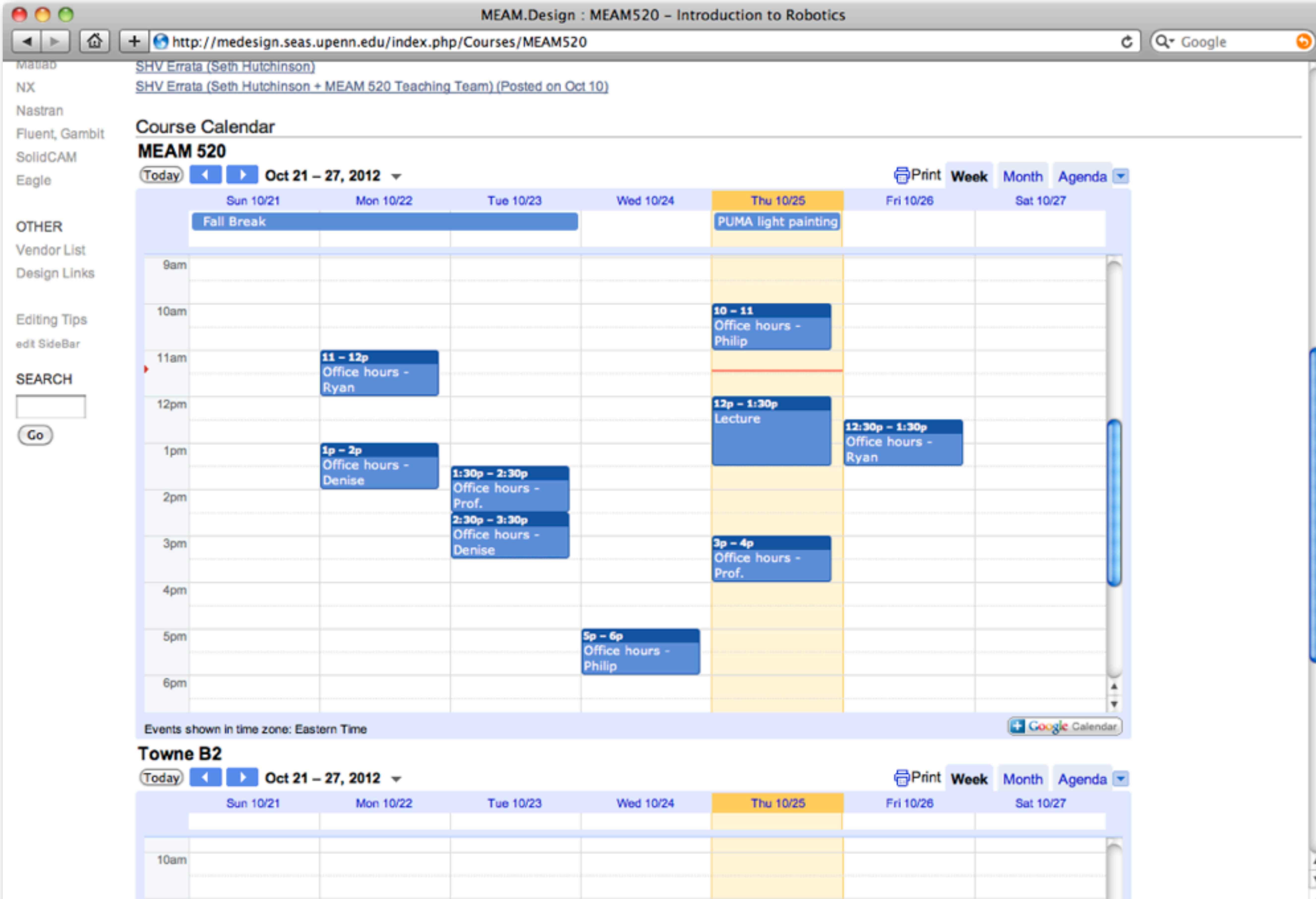
(note: all items are due at 5:00 p.m. unless otherwise specified)

Resources

Piazza Forum
Blackboard (Gradebook and Lecture Recordings)
Mathworks Matlab Tutorial
MEAM 520 Matlab Tutorial
Textbook: Robot Modeling and Control by Spong, Hutchinson, and Vidyasagar
SHV Errata (Seth Hutchinson)
SHV Errata (Seth Hutchinson + MEAM 520 Teaching Team) (Posted on Oct 10)

Course Calendar

MEAM 520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SHV Errata (Seth Hutchinson + MEAM 520 Teaching Team) (Posted on Oct 10)
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Fri 10/26
Sat 10/27
Fall Break
PUMA light painting
9am
10am
11am
12pm
1pm
2pm
3pm
4pm
5pm
6pm
10 – 11 Office hours - Philip
11 – 12p Office hours - Ryan
12p – 1:30p Lecture
12:30p – 1:30p Office hours - Ryan
1p – 2p Office hours - Denise
1:30p – 2:30p Office hours - Prof.
2:30p – 3:30p Office hours - Denise
3p – 4p Office hours - Prof.
5p – 6p Office hours - Philip
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Sat 10/27
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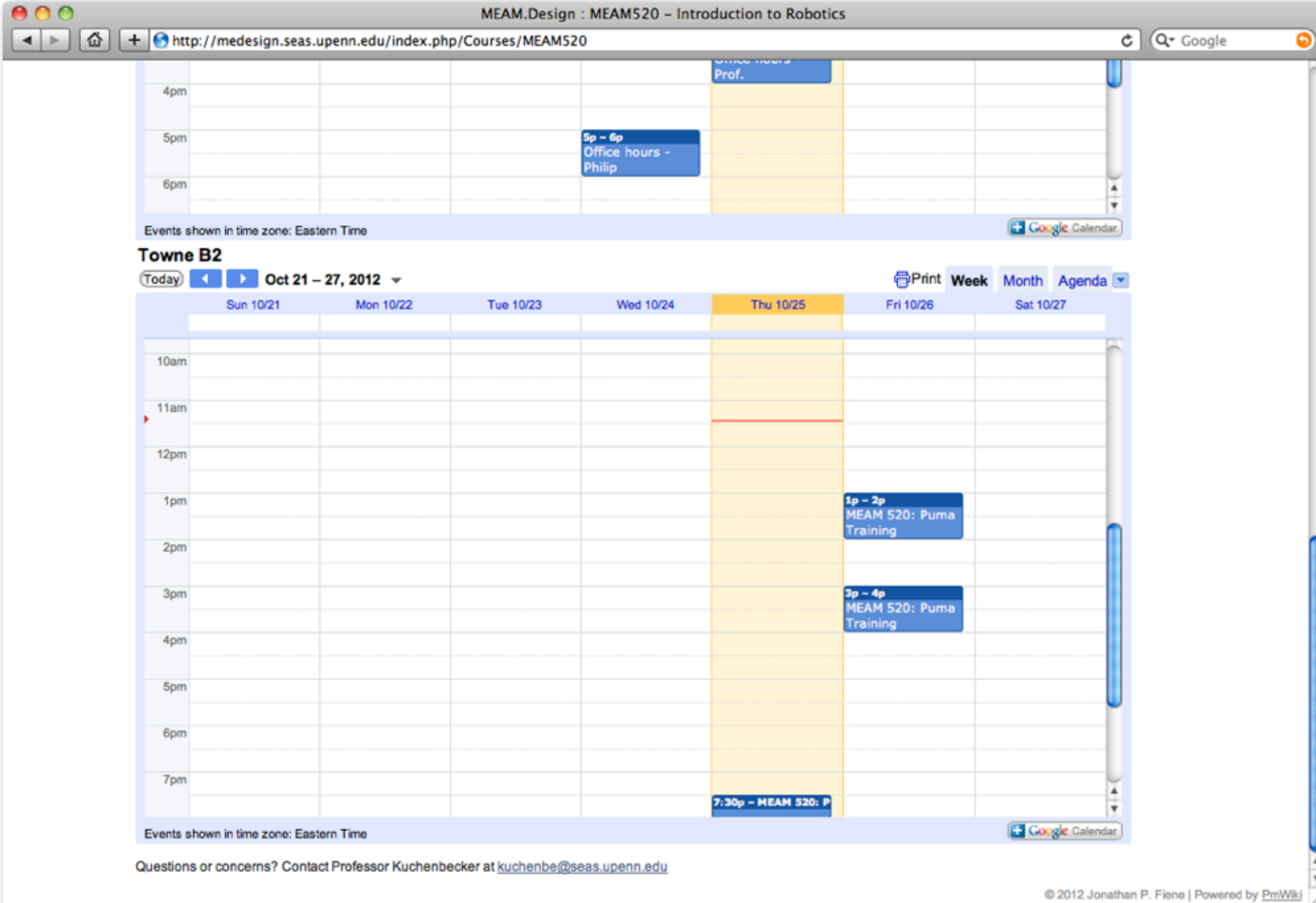
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MEAM 520: Puma Training
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MEAM 520: Puma Training
4pm
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7pm
7:30p – MEAM 520: P
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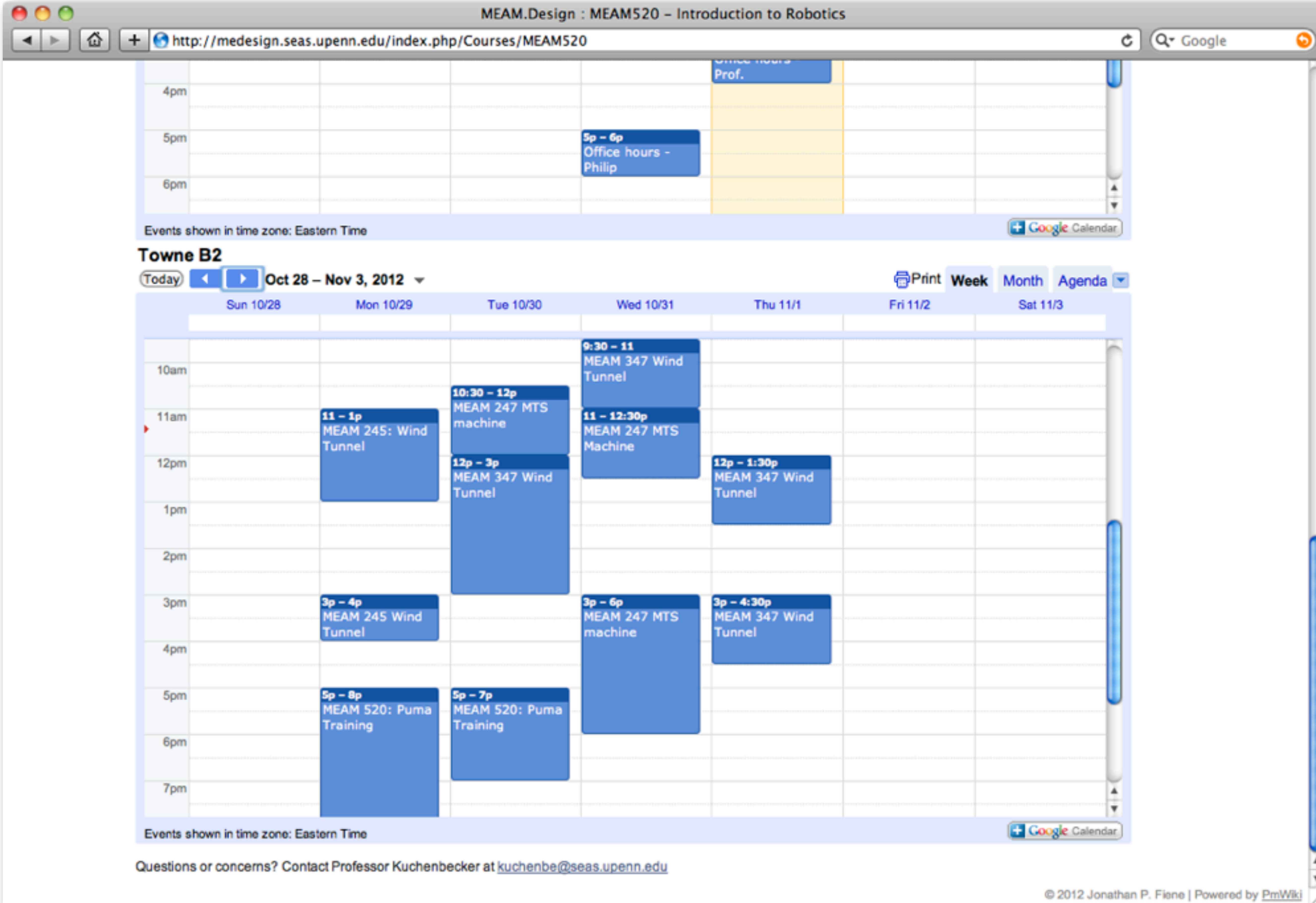
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Thu 11/1
Fri 11/2
Sat 11/3
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4pm
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6pm
7pm
9:30 – 11
MEAM 347 Wind Tunnel
10:30 – 12p
MEAM 247 MTS machine
11 – 1p
MEAM 245: Wind Tunnel
11 – 12:30p
MEAM 247 MTS Machine
12p – 3p
MEAM 347 Wind Tunnel
12p – 1:30p
MEAM 347 Wind Tunnel
3p – 4p
MEAM 245 Wind Tunnel
3p – 6p
MEAM 247 MTS machine
3p – 4:30p
MEAM 347 Wind Tunnel
5p – 8p
MEAM 520: Puma Training
5p – 7p
MEAM 520: Puma Training
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Where is the PUMA?

B2 Towne


TOWNE BUILDING


TOWNE BUILD


TOWNE BUILDING
ROOMS B2-B11
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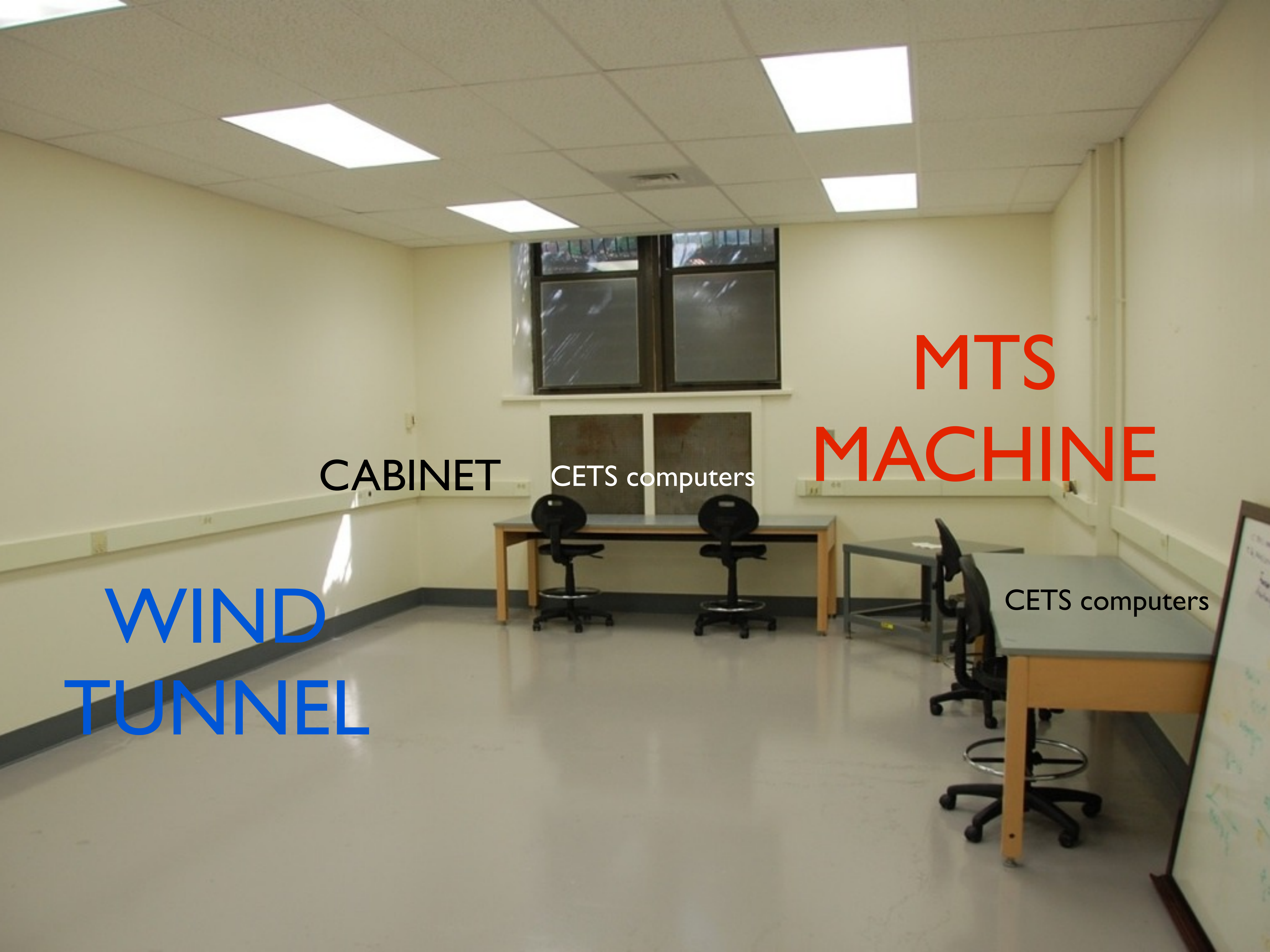
TOWNE BUILDING

B2


MTS
MACHINE
CABINET
CETS computers
WIND
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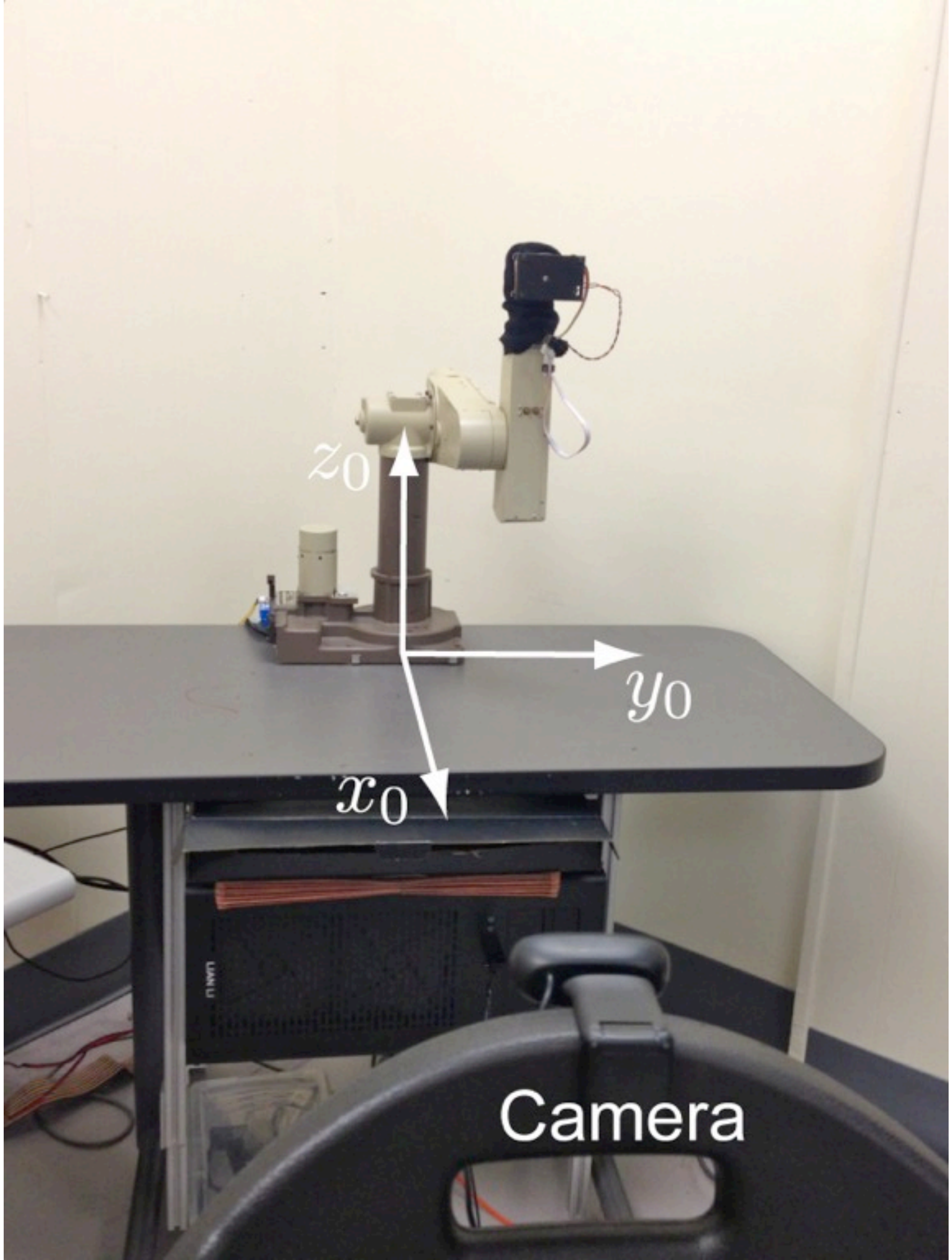
CETS computers

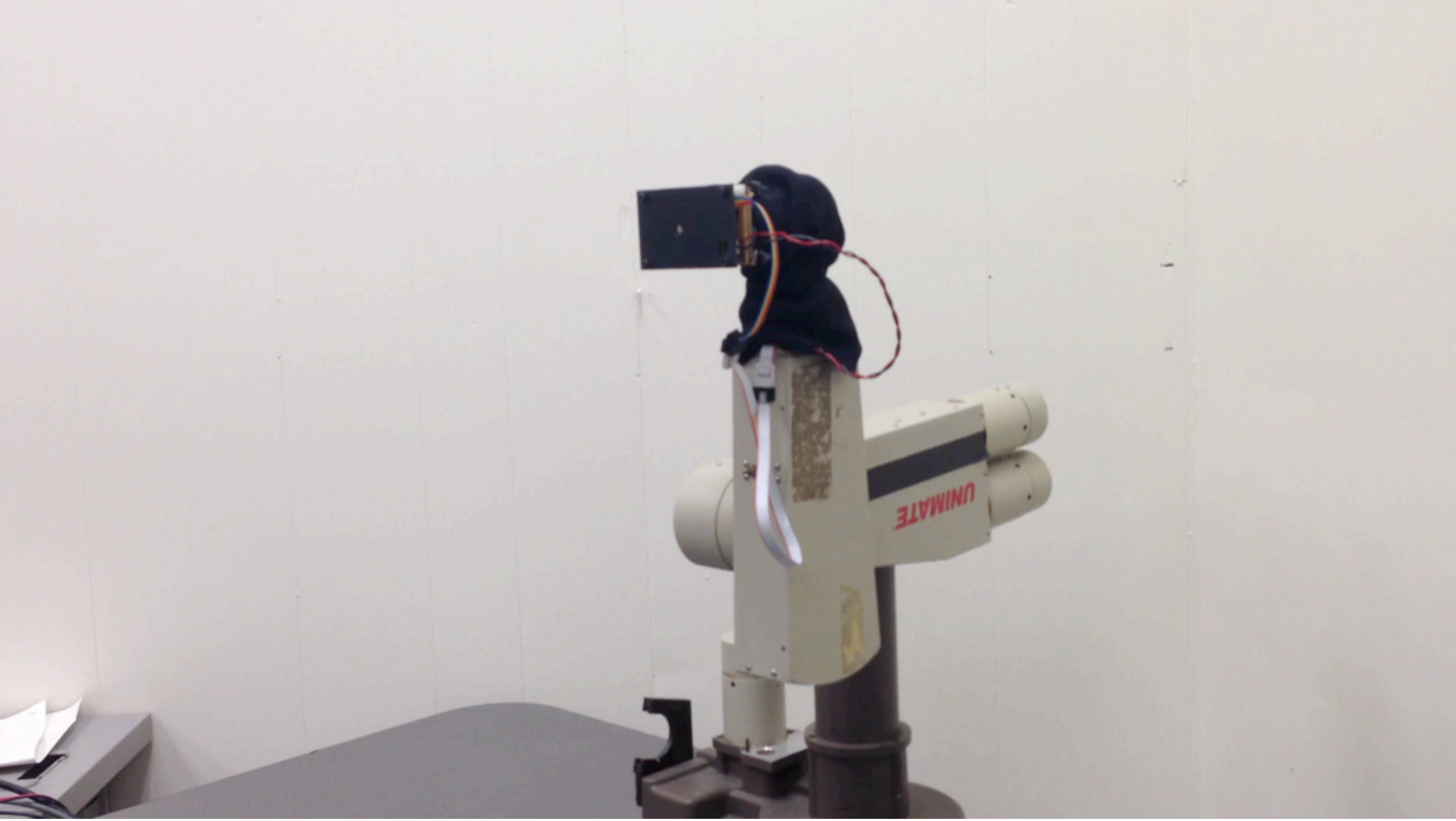

PUMA


z_0
y_0
x_0
Camera

Rules for B2

1. No food or drink allowed. Water bottles are okay.
2. Do not touch the wind tunnel.
3. Do not touch the MTS machine.
4. Do not touch the cabinet in the corner.
5. Do not open the windows.
6. Do not turn the lights off when students from other classes are using the other equipment.
7. Be persistent with the card swipe (~8 tries?).
8. Feel free to use the CETS computers.
9. Be careful with the robot.


EMERGENCY
STOP


UNIMATE

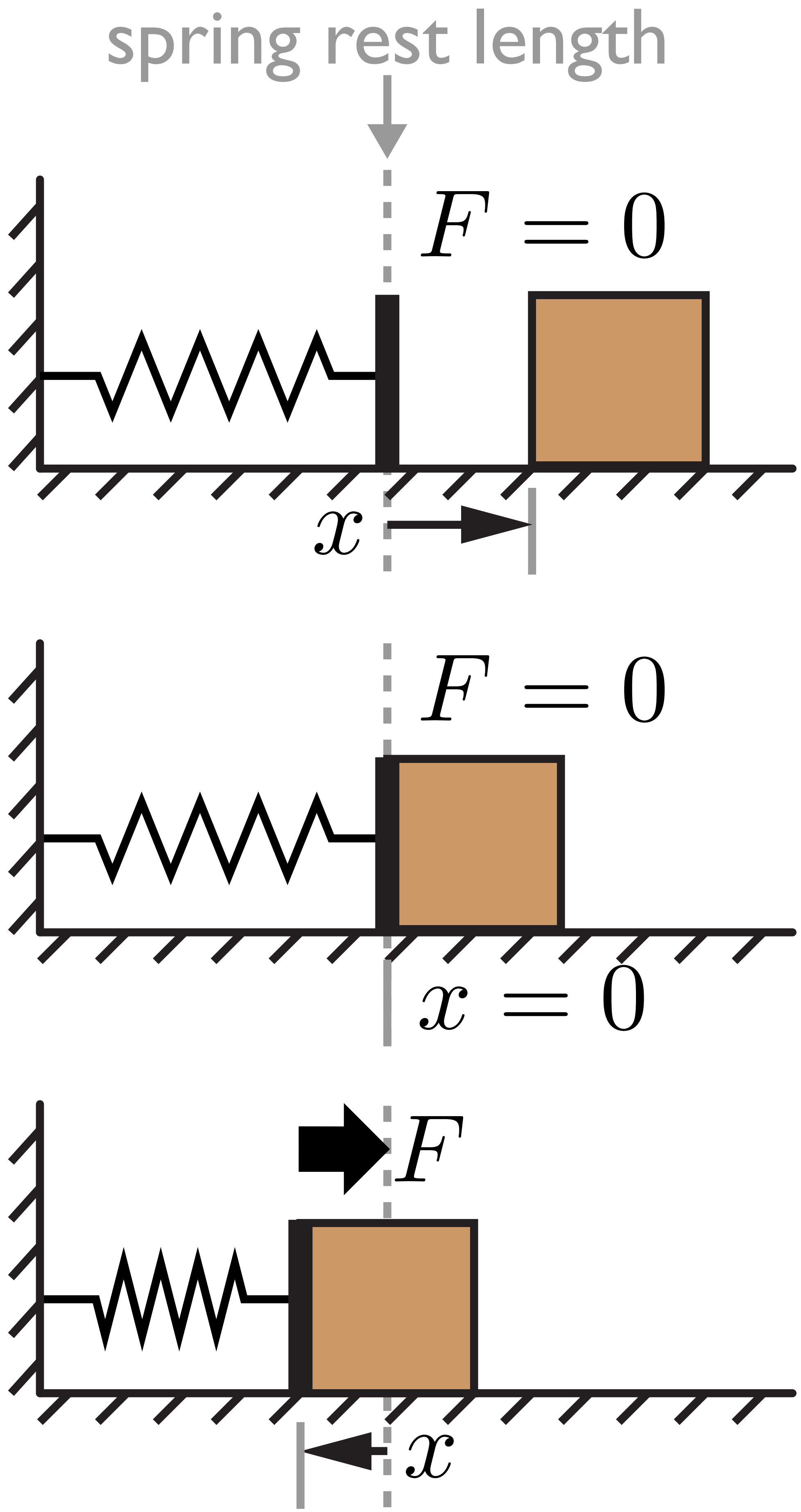
How does the real robot differ from the simulator?

Simulator is kinematic only, but the robot has dynamics: friction, inertia, gravity, backlash, compliance, possible mis-calibration, and torque limits. (electrical dynamics too!)

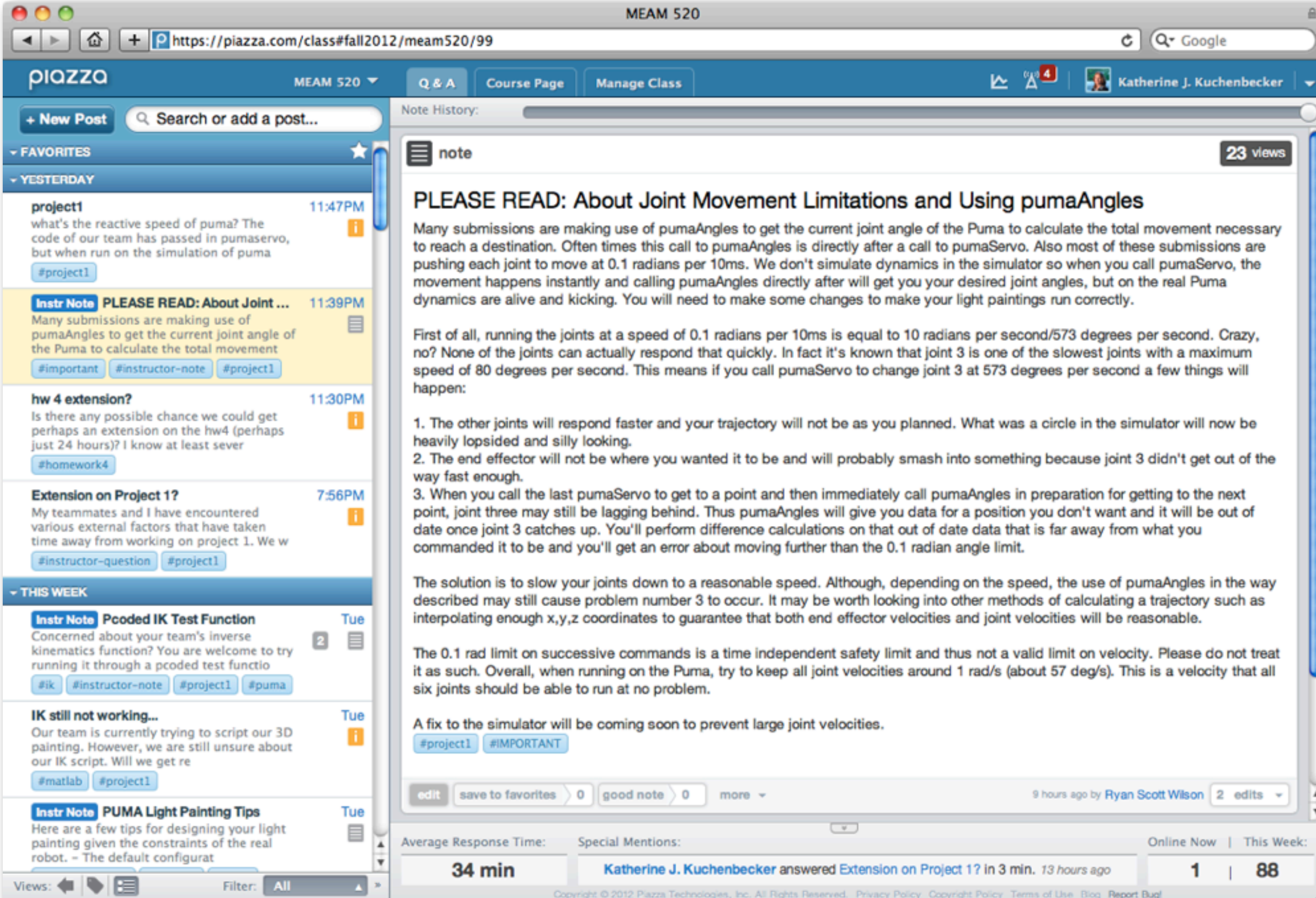
The robot's joint angle sensors are quantized.

Time can be accelerated or slowed down in the simulator.

The robot can hurt you and itself.



spring rest length
$F = 0$
x
$F = 0$
$x = 0$
F
x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project1
11:47PM
what's the reactive speed of puma? The code of our team has passed in pumaservo, but when run on the simulation of puma
#project1
Instr Note
PLEASE READ: About Joint ...
11:39PM
Many submissions are making use of pumaAngles to get the current joint angle of the Puma to calculate the total movement
#important
#instructor-note
#project1
hw 4 extension?
11:30PM
Is there any possible chance we could get perhaps an extension on the hw4 (perhaps just 24 hours)? I know at least sever
#homework4
Extension on Project 1?
7:56PM
My teammates and I have encountered various external factors that have taken time away from working on project 1. We w
#instructor-question
#project1
THIS WEEK
Instr Note
Pcoded IK Test Function
Tue
Concerned about your team's inverse kinematics function? You are welcome to try running it through a pcoded test functio
#ik
#instructor-note
#project1
#puma
IK still not working...
Tue
Our team is currently trying to script our 3D painting. However, we are still unsure about our IK script. Will we get re
#matlab
#project1
Instr Note
PUMA Light Painting Tips
Tue
Here are a few tips for designing your light painting given the constraints of the real robot. - The default configurat
Views:
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All
Note History:
note
23 views
PLEASE READ: About Joint Movement Limitations and Using pumaAngles
Many submissions are making use of pumaAngles to get the current joint angle of the Puma to calculate the total movement necessary to reach a destination. Often times this call to pumaAngles is directly after a call to pumaServo. Also most of these submissions are pushing each joint to move at 0.1 radians per 10ms. We don't simulate dynamics in the simulator so when you call pumaServo, the movement happens instantly and calling pumaAngles directly after will get you your desired joint angles, but on the real Puma dynamics are alive and kicking. You will need to make some changes to make your light paintings run correctly.
First of all, running the joints at a speed of 0.1 radians per 10ms is equal to 10 radians per second/573 degrees per second. Crazy, no? None of the joints can actually respond that quickly. In fact it's known that joint 3 is one of the slowest joints with a maximum speed of 80 degrees per second. This means if you call pumaServo to change joint 3 at 573 degrees per second a few things will happen:
1. The other joints will respond faster and your trajectory will not be as you planned. What was a circle in the simulator will now be heavily lopsided and silly looking.
2. The end effector will not be where you wanted it to be and will probably smash into something because joint 3 didn't get out of the way fast enough.
3. When you call the last pumaServo to get to a point and then immediately call pumaAngles in preparation for getting to the next point, joint three may still be lagging behind. Thus pumaAngles will give you data for a position you don't want and it will be out of date once joint 3 catches up. You'll perform difference calculations on that out of date data that is far away from what you commanded it to be and you'll get an error about moving further than the 0.1 radian angle limit.
The solution is to slow your joints down to a reasonable speed. Although, depending on the speed, the use of pumaAngles in the way described may still cause problem number 3 to occur. It may be worth looking into other methods of calculating a trajectory such as interpolating enough x,y,z coordinates to guarantee that both end effector velocities and joint velocities will be reasonable.
The 0.1 rad limit on successive commands is a time independent safety limit and thus not a valid limit on velocity. Please do not treat it as such. Overall, when running on the Puma, try to keep all joint velocities around 1 rad/s (about 57 deg/s). This is a velocity that all six joints should be able to run at no problem.
A fix to the simulator will be coming soon to prevent large joint velocities.
#project1
#IMPORTANT
edit
save to favorites
0
good note
0
more
9 hours ago by Ryan Scott Wilson
2 edits
Average Response Time:
34 min
Special Mentions:
Katherine J. Kuchenbecker answered Extension on Project 1? in 3 min. 13 hours ago
Online Now | This Week:
1 | 88
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Questions ?

Homework 4 due Friday 11/2

Homework 4: Velocity Kinematics and Jacobians

MEAM 520, University of Pennsylvania
Katherine J. Kuchenbecker, Ph.D.

October 23, 2012

This assignment is due on **Friday, November 2 (updated)**, by 5:00 p.m. sharp. You should aim to turn the paper part in during class the day before. If you don't finish until later in the day, you can turn it in to Professor Kuchenbecker's office, Towne 224. Late submissions will be accepted until 5:00 p.m. on Monday, November 5, but they will be penalized by 25%. After that deadline, no further assignments may be submitted.

You may talk with other students about this assignment, ask the teaching team questions, use a calculator and other tools, and consult outside sources such as the Internet. To help you actually learn the material, what you write down should be your own work, not copied from a peer or a solution manual.

Written Problems *(60 points)*

This entire assignment is written and consists of two significantly adapted problems from the textbook, *Robot Modeling and Control* by Spong, Hutchinson, and Vidyasagar (SHV). Please follow the extra clarifications and instructions on both questions. Write in pencil, show your work clearly, box your answers, and staple your pages together.

1. **Adapted SHV 4-20, page 160 – Three-link Cylindrical Manipulator** ***(30 points)***
   The book works out the DH parameters and the transformation matrix T_3^0 for this robot on pages 85 and 86; you are welcome to use these results directly without rederiving them.

   (a) Use the position of the end-effector in the base frame to calculate the 3×3 linear velocity Jacobian J_v for the three-link cylindrical manipulator of Figure 3.7 on page 85.

   (b) Use the positions of the origins o_i and the orientations of the z-axes z_i to calculate the 3×3 linear velocity Jacobian J_v for the same robot. You should get the same answer as before.

   (c) Find the 3×3 angular velocity Jacobian J_ω for the same robot.

   (d) Find this robot's 6×3 Jacobian J.

   (e) Imagine this robot is at $\theta_1 = \pi/2$ rad, $d_2 = 0.2$ m, and $d_3 = 0.3$ m, and its joint velocities are $\dot{\theta}_1 = 0.1$ rad/s, $\dot{d}_2 = 0.25$ m/s, and $\dot{d}_3 = -0.05$ m/s. What is v_3^0, the linear velocity vector of the end-effector with respect to the base frame, expressed in the base frame? Make sure to provide units with your answer.

   (f) For the same situation, what is ω_3^0, the angular velocity vector of the end-effector with respect to the base frame, expressed in the base frame? Make sure to provide units with your answer.

   (g) Use your answers from above to derive the singular configurations of the arm, if any. Here we are concerned with the linear velocity of the end-effector, not its angular velocity. Be persistent with the calculations; they should reduce to something nice.

   (h) Sketch the cylindrical manipulator in each singular configuration that you found, and explain what effect the singularity has on the robot's motion in that configuration.

2. **Adapted SHV 4-18, page 160 – Three-link Spherical Manipulator** ***(30 points)***
   The book does not seem to work out the forward kinematics for this robot anywhere. Please use the diagram on the left side of Figure 1.12 on page 15 in SHV to define the positive joint directions and the zero configuration for the robot. If we additionally choose the x_0 axis to point in the direction the robot arm points in the zero configuration, you can calculate that the tip of the spherical manipulator is at $[x \;\; y \;\; z]^T = [c_1c_2d_3 \;\; s_1c_2d_3 \;\; d_1 - s_2d_3]^T$. In this expression θ_1, θ_2, and d_3 are the joint variables; s_i is $\sin\theta_i$ and c_i is $\cos\theta_i$; and d_1 is a constant.

   (a) Calculate the 3×3 linear velocity Jacobian J_v for the spherical manipulator with no offsets shown in the left side of Figure 1.12 on page 15 of SHV. You may use any method you choose.

   (b) Find the 3×3 angular velocity Jacobian J_ω for the same robot.

   (c) Find this robot's 6×3 Jacobian J.

   (d) Imagine this robot is at $\theta_1 = \pi/4$ rad, $\theta_2 = 0$ rad, and $d_3 = 1$ m. What is ω_3^0, the angular velocity vector of the end-effector with respect to the base frame, expressed in the base frame, as a function of the joint velocities $\dot{\theta}_1$, $\dot{\theta}_2$, and $\dot{d}_3$? Make sure to provide units for any coefficients in these equations, if needed.

   (e) For the same configuration described in the previous question, what is v_3^0, the linear velocity vector of the end-effector with respect to the base frame, expressed in the base frame, as a function of the joint velocities $\dot{\theta}_1$, $\dot{\theta}_2$, and $\dot{d}_3$? Provide units for any coefficients in these equations, if needed.

   (f) What instantaneous joint velocities should I choose if the robot is in the configuration described in the previous questions and I want its tip to move at $v_3^0 = [0 \text{ m/s} \;\; 0.5 \text{ m/s} \;\; 0.1 \text{ m/s}]^T$? Make sure to provide units with your answer.

   (g) Use your answers from above to derive the singular configurations of the arm, if any. Here we are concerned with the linear velocity of the end-effector, not its angular velocity. Be persistent with the calculations; they should reduce to something nice.

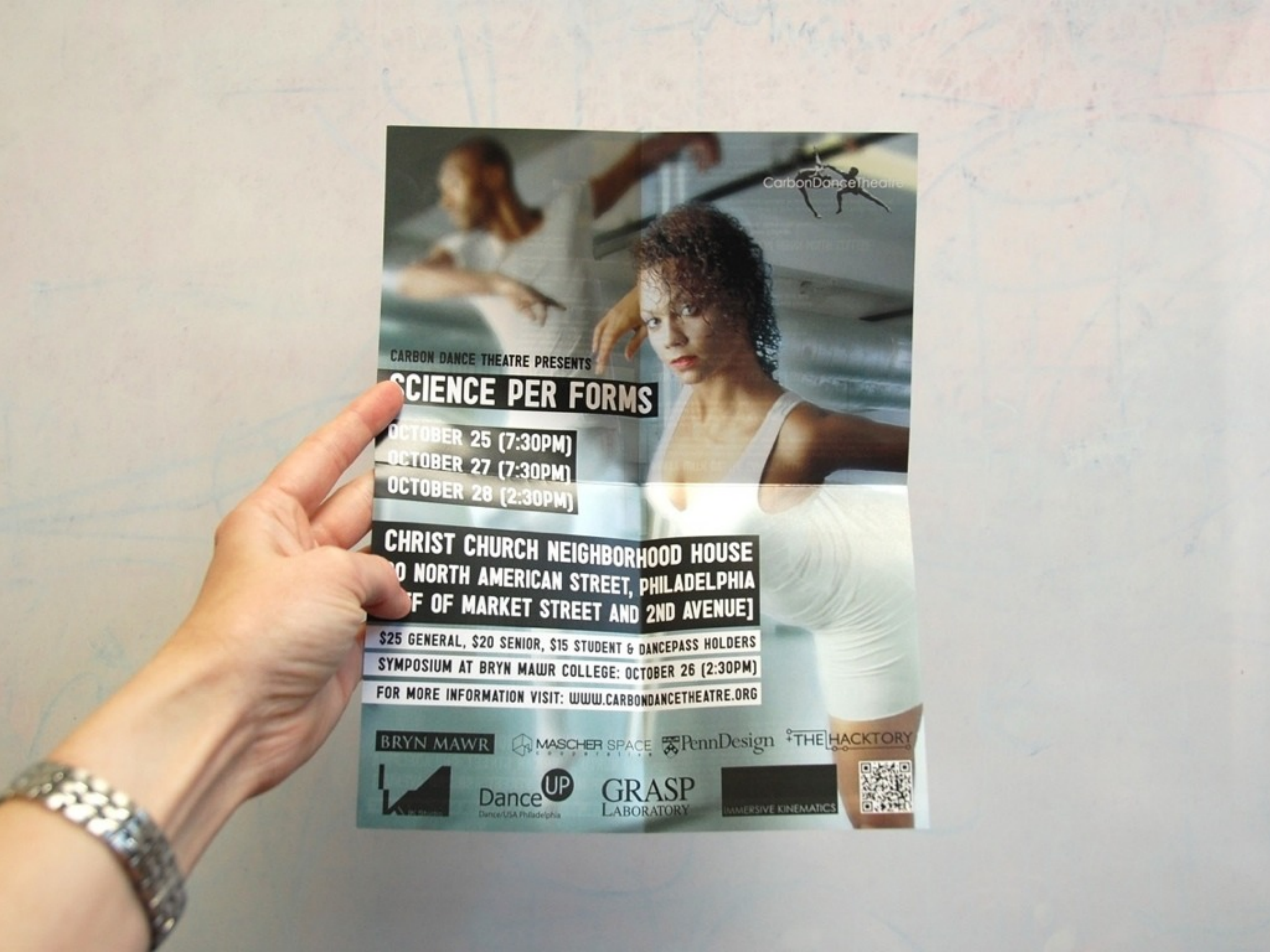
   (h) Sketch the cylindrical manipulator in each singular configuration that you found, and explain what effect the singularity has on the robot's motion in that configuration.

   (i) Would the singular configuration sketches you just drew be any different if we had chosen different positive directions for the joint coordinates? What if we had selected a different zero configuration for this robot? Explain.

3. **Optional Extra Credit – Visualizing the Linear Velocity Jacobian** ***(unknown points)***
   If you have time and interest, feel free to try this optional extra-credit problem. Modify your solution for the PUMA robot animation in Homework 3 (`puma_robot_yourpennkey.m`) in the following ways:

   - Rename the file `jacobian_yourpennkey.m`
   - Eliminate the spherical wrist, so that end-effector is at the origin of frame 3 (the wrist center).
   - Remove the offsets by setting b and d to zero. This should give you an articulated manipulator.
   - Change the zero configuration as follows: when all three angles are zero, the arm should be horizontal and pointing in the direction of the positive x_0 axis. Although this is not what is shown in Figure 4.5 on page 145 in SHV, I think this is the zero configuration they used.
   - Use the expression for J_{11} on page 144 in SHV to augment the visualization of the robot with three lines that go through the tip of the robot and show the direction in which the tip will move if you have only one non-zero joint velocity. Make the line for $\dot{\theta}_1$ red, the line for $\dot{\theta}_2$ green, and the line for $\dot{\theta}_3$ blue. Feel free to adjust other plotting parameters as needed.
   - Check your solution with the provided motion modes, and feel free to create a new motion mode that showcases the Jacobian augmentation you added.

   Submit your code as an attachment to an email to `meam520@seas.upenn.edu` with the subject *Jacobian Extra Credit: Your Name*, replacing *Your Name* with your name.


CarbonDanceTheatre
CARBON DANCE THEATRE PRESENTS
SCIENCE PER FORMS
OCTOBER 25 (7:30PM)
OCTOBER 27 (7:30PM)
OCTOBER 28 (2:30PM)
CHRIST CHURCH NEIGHBORHOOD HOUSE
0 NORTH AMERICAN STREET, PHILADELPHIA
F OF MARKET STREET AND 2ND AVENUE]
$25 GENERAL, $20 SENIOR, $15 STUDENT & DANCEPASS HOLDERS
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FOR MORE INFORMATION VISIT: WWW.CARBONDANCETHEATRE.ORG
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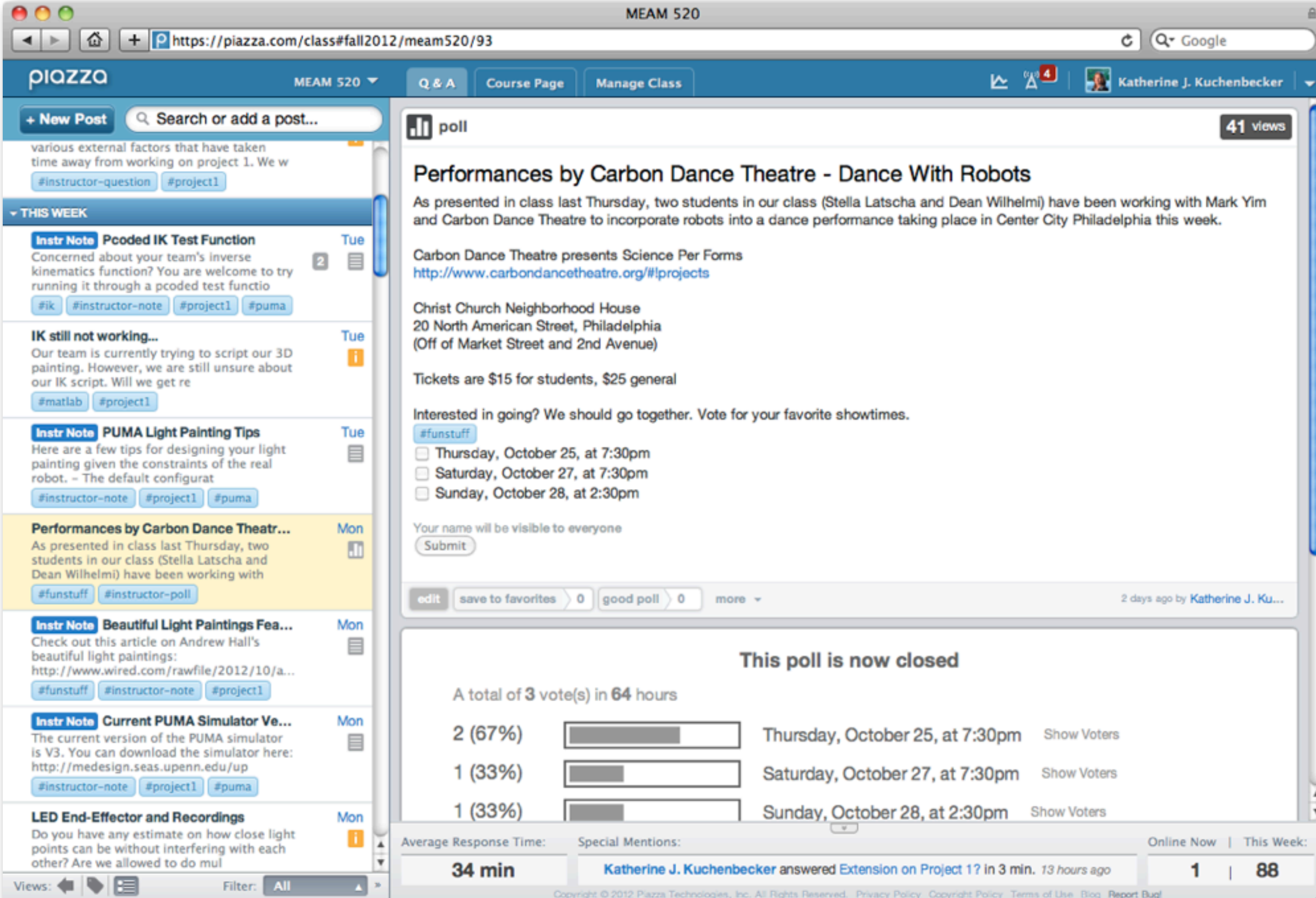
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Katherine J. Kuchenbecker
+ New Post
Search or add a post...
various external factors that have taken time away from working on project 1. We w
#instructor-question #project1
THIS WEEK
Instr Note Pcoded IK Test Function
Tue
Concerned about your team's inverse kinematics function? You are welcome to try running it through a pcoded test functio
#ik #instructor-note #project1 #puma
IK still not working...
Tue
Our team is currently trying to script our 3D painting. However, we are still unsure about our IK script. Will we get re
#matlab #project1
Instr Note PUMA Light Painting Tips
Tue
Here are a few tips for designing your light painting given the constraints of the real robot. - The default configurat
#instructor-note #project1 #puma
Performances by Carbon Dance Theatr...
Mon
As presented in class last Thursday, two students in our class (Stella Latscha and Dean Wilhelmi) have been working with
#funstuff #instructor-poll
Instr Note Beautiful Light Paintings Fea...
Mon
Check out this article on Andrew Hall's beautiful light paintings: http://www.wired.com/rawfile/2012/10/a...
#funstuff #instructor-note #project1
Instr Note Current PUMA Simulator Ve...
Mon
The current version of the PUMA simulator is V3. You can download the simulator here: http://medesign.seas.upenn.edu/up
#instructor-note #project1 #puma
LED End-Effector and Recordings
Mon
Do you have any estimate on how close light points can be without interfering with each other? Are we allowed to do mul
Views:
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poll
41 views
Performances by Carbon Dance Theatre - Dance With Robots
As presented in class last Thursday, two students in our class (Stella Latscha and Dean Wilhelmi) have been working with Mark Yim and Carbon Dance Theatre to incorporate robots into a dance performance taking place in Center City Philadelphia this week.
Carbon Dance Theatre presents Science Per Forms
http://www.carbondancetheatre.org/#!projects
Christ Church Neighborhood House
20 North American Street, Philadelphia
(Off of Market Street and 2nd Avenue)
Tickets are $15 for students, $25 general
Interested in going? We should go together. Vote for your favorite showtimes.
#funstuff
Thursday, October 25, at 7:30pm
Saturday, October 27, at 7:30pm
Sunday, October 28, at 2:30pm
Your name will be visible to everyone
Submit
edit
save to favorites 0
good poll 0
more
2 days ago by Katherine J. Ku...
This poll is now closed
A total of 3 vote(s) in 64 hours
2 (67%) Thursday, October 25, at 7:30pm Show Voters
1 (33%) Saturday, October 27, at 7:30pm Show Voters
1 (33%) Sunday, October 28, at 2:30pm Show Voters
Average Response Time:
34 min
Special Mentions:
Katherine J. Kuchenbecker answered Extension on Project 1? in 3 min. 13 hours ago
Online Now | This Week:
1 | 88
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Confirmed Midterm Date

Thursday, November 8, in class

Covers everything on Homework 1 through 4
plus Project 1