

**Individual Problem Set:**

**Total marks:** 100

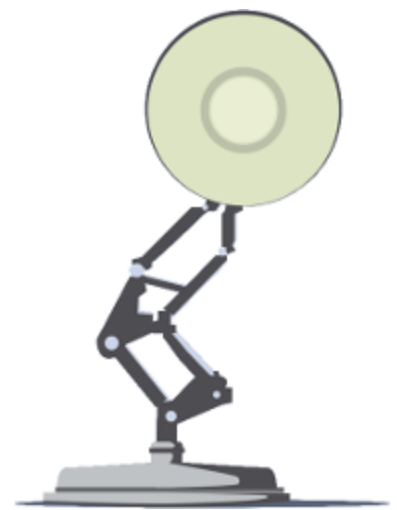
**Due Date:** Monday, November 17, 2014 (at 11:59pm, AEST)  
(Extended from November 14 due to G20 Public Holiday)

**Note:** The problem consists of five questions of varying difficulty (and point) please **answer 100 points worth of questions**. Please complete just 100 point worth! **No** extra credit will be given for answering extra questions. This assignment is worth **12.5%** of the final course mark. Please submit answers via [Platypus](#). It is requested that solutions, including equations, should be typed please. This assignment is an **individual** assignment and should represent your effort only. Thank you very much. :-)

**(1) A Light Kinematics Problem [20 points]**

*How many robot degrees of freedom does it take to screw in a light bulb?*

Start with the assumption that we have single Edison-screw light bulb that is unpacked and resting on a standard office table. It needs to be placed into a Luxo L-1 lamp also on this table. Please **justify** and clearly state all other assumptions.

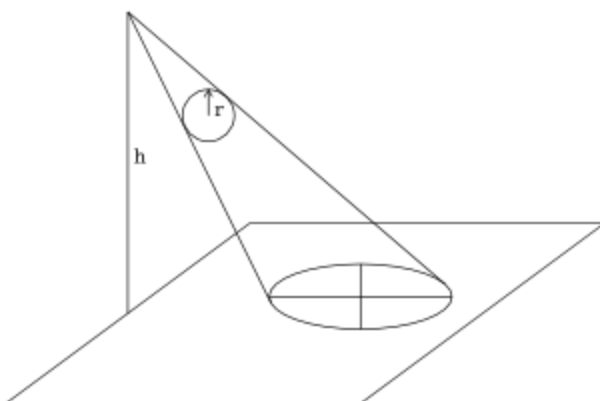


**(2) X-Ray Vision [20 points]**

An orthopedic surgeon needs to position and orient a metallic sphere (of radius  $r$ ) as part of a minimally invasive procedure. They observe that under X-Ray, the sphere appears as an ellipse and that the aspect ratio and size of the image changes in response to the sphere position.

Assume that the X-Ray system may be considered a point source that projects as a skewed cone that contains the sphere of arbitrary position and orientation to the imaging plane detector.

*Estimate the sphere's 3D spatial position using the image (aspect ratio) of the ellipse*

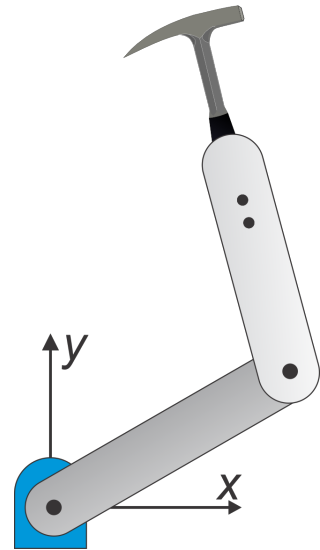


[Extra Credit + 20 points] Imagine we replace the sphere with a circular disk. Explain the procedure for recovering the position *and* orientation of this circular disk, again using just the image of this disk on the X-Ray.

**(3) Hit the Nail on the Head [20 Points]**

As a literary construction, consider a planar manipulator arm tasked with hitting a nail using a hammer. At the endpoint, the hammer is in contact with a nail and applies the force  $\mathbf{F}=[F_x, F_y]$ .

- A. **First.** Find the equivalent joint torques corresponding to the endpoint force  $\mathbf{F}$  assuming that the joint mechanisms are frictionless.
- B. **Second,** Find the equivalent joint torques corresponding to the endpoint force  $\mathbf{F}$  assuming that the joint mechanisms have friction (given by a viscous coefficient  $\mathbf{b}$ ).



**(4) Sifting Through: SIFT's Invariances [20 Points]**

The Scale invariant feature transform (SIFT) is a popular feature descriptor, but it is no panacea. Clearly, it is scale-invariant. In this case by extracting features that are stable in both location and scale instead of extracting and matching features at many different scales levels. Let's consider where SIFT's limits and how to break them. Briefly **consider** and **justify (i.e., why? or why not?)** the following:

- A. **Rotational Invariance.** Does the "dominant orientation" of SIFT make the features (in-plane) rotationally invariant?
- B. **Affine Invariance.** Is SIFT affine invariant? If not, are the other detectors in OpenCV affine invariant?  
[Hint: The other detectors of OpenCV include: Maximally Stable Extremal Region (MSER), Features from Accelerated Segment Test (FAST), etc. Please see [OpenCV's Feature Detection and Description documentation](#)]
- C. **Lighting Invariance.** Is SIFT invariant to changes in local appearance of image patches?
- D. **Colour Invariance.** Is SIFT invariant to changes in the colour of an object (e.g., imagine we have two identical cups, but they vary only in their color, will SIFT match their features)?

**(5) Should ORB be in Your Next ROBot? [20 Points]**

The ORB (Oriented FAST and Rotated BRIEF) is a newer detector and is described in the ICCV 2011 paper by [Rublee, et al., "ORB: an efficient alternative to SIFT or SURF."](#) It is also part of [OpenCV](#). Briefly, in what ways is ORB better than SIFT? In what ways is SIFT better than ORB? For the task of matching cups using features, which would be better SIFT or ORB? In all cases, briefly justify and explain.

**(6) Raises On More Than Karma. [20 Points]**

[Lab 3](#) is motivated by filling orders quickly. Clearly, doing operations in the right order is faster and potentially more profitable. Consider a mechanism for optimizing the performance of this the arm in [Lab 3](#).

- A. **“Express!”**: Research a scheme that optimizes the sequence of operations for filling the cups such that an order is completed in time-optimal manner. What class of robotics problem is this? Computationally how “hard” is this problem? Explain **specifically** and **analytically** how the method found will determine the optimal (or near optimal) solution.
- B. **Energy Efficiency**: How would the method found/developed in the previous part (A) need to be changed so as to optimize for energy efficiency of the system if the unit was constructed only using Dynamixel AX-12a motors. How might the arm design effect the total system efficiency in this case?

**(7) Two Much To Juggle? [20 Points]**

Consider the [cart-pole \(inverted pendulum\) problem](#). Please describe the dynamics for a double pendulum (i.e., a “2-pendulum”).

- A. **Cart & Pole, Pole Placement**. Using a linearization of the model you find, then design a pole placement controller.
- B. **Swing up**. Comment on whether this controller can perform a swing-up?
- C. **More is less?** Comment on if this be generalized to an N-pendulum system? (i.e., what happens to the dynamics of this as  $N \rightarrow \infty$ ?)

**(8) Two Can Play at This Game [40 Points]**

As an extension to [Lab 3](#), consider a case where two [Lab 3](#) robot arms kits may be combined so as to fill orders faster and serve more cups.

- A. **Issues at Hand**. Briefly explain the issues that having two arms would introduce to this problem. How would address these issues?
- B. **A Redundant Arm?** Another option could be to merge the two kits and make one arm that combines the 8 motors in both (Dynamixel) kits. For the cup filling problem (as in [Lab 3](#)), for what cases would the arm be over-actuated or redundant? Briefly explain which configuration would be better (one combined arm of or two separate arms)?
- C. **Specify/Design an Arm(s)**. Based on the conclusions you have drawn in the previous parts (A and B), please design/specify a robot configuration that uses the 8 motors to provide the necessary motion. You need only provide the kinematic configuration for the arm.  
[Note: Denavit-Hartenberg Parameters are fine. If you choose two arms and the two arms are identical, then you may simply note this]
- D. **Velocity Relationships**. For this configuration, what is the Jacobian relationship (i.e.,  $\dot{q} = J(q)^{-1}v$  or  $\dot{q} = J(q)^+v$  [where + indicates the left pseudo-inverse] depending on your configuration). What is the rank of the Jacobean? What is its dimension? Does it have a Null space? If so, what does this indicate (i.e., what does a projection in the Null space imply)?