MEAM 520

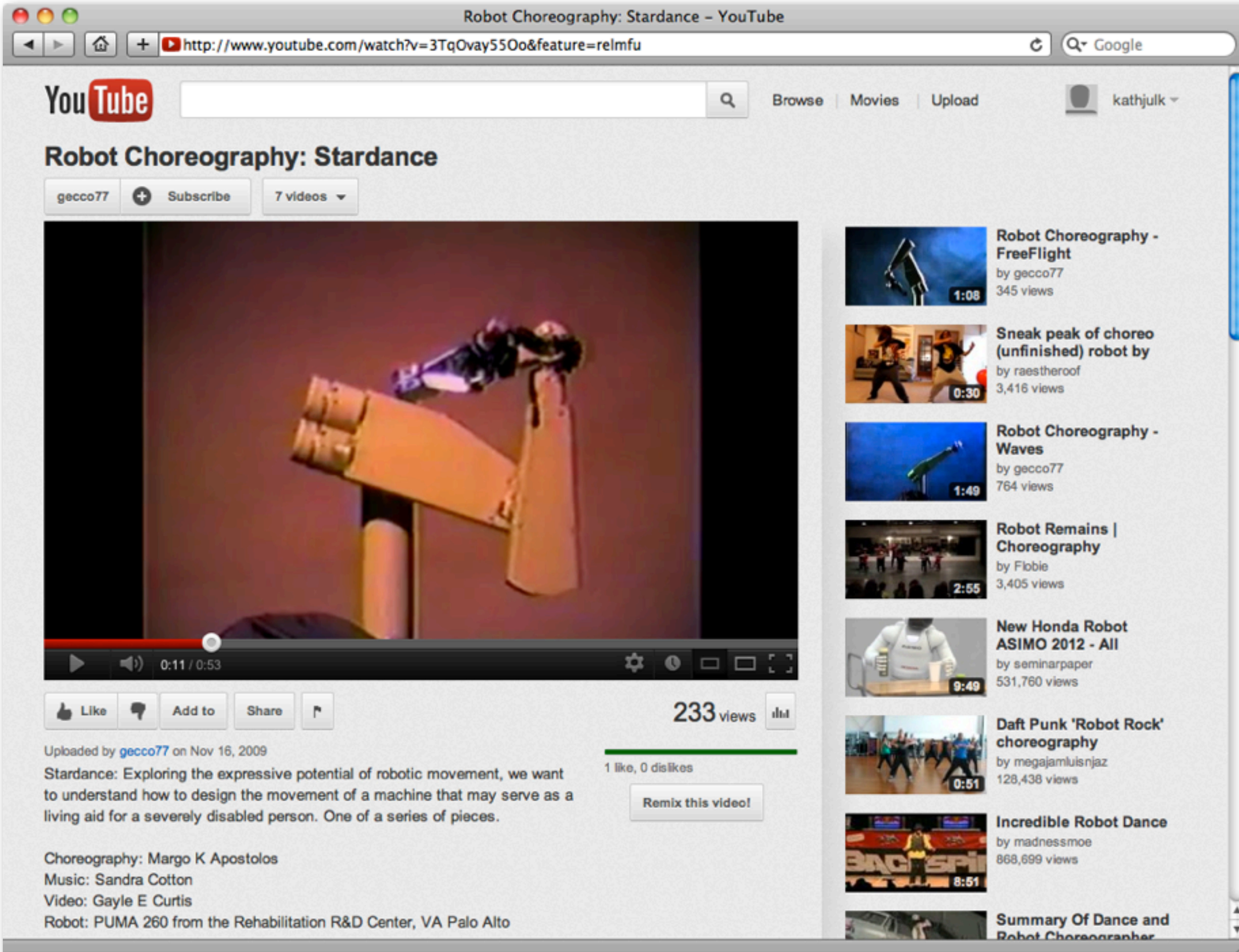
The Puma 260 and Project 1

Katherine J. Kuchenbecker, Ph.D.

General Robotics, Automation, Sensing, and Perception Lab (GRASP)

MEAM Department, SEAS, University of Pennsylvania

Lecture 9: October 4, 2012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Stardance: Exploring the expressive potential of robotic movement, we want to understand how to design the movement of a machine that may serve as a living aid for a severely disabled person. One of a series of pieces.
Choreography: Margo K Apostolos
Music: Sandra Cotton
Video: Gayle E Curtis
Robot: PUMA 260 from the Rehabilitation R&D Center, VA Palo Alto
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Robot Choreography - FreeFlight
by gecco77
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Sneak peak of choreo (unfinished) robot by
by raestheroof
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by Flobie
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Daft Punk 'Robot Rock' choreography
by megajamluisnjaz
128,438 views
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Incredible Robot Dance
by madnessmoe
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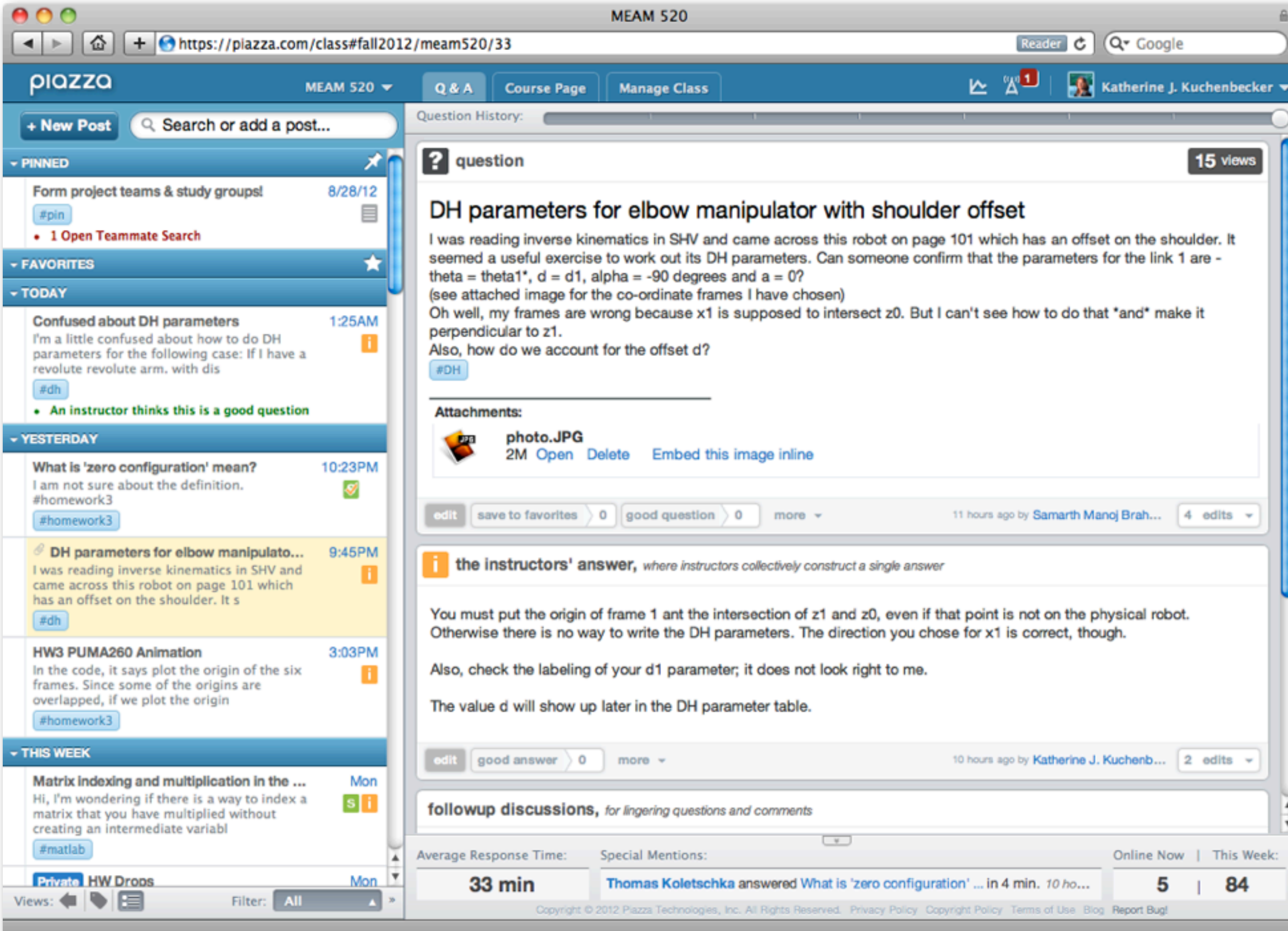
Summary Of Dance and

A few good questions about DH parameters...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TODAY
Confused about DH parameters
1:25AM
I'm a little confused about how to do DH parameters for the following case: If I have a revolute revolute arm. with dis
#dh
An instructor thinks this is a good question
YESTERDAY
What is 'zero configuration' mean?
10:23PM
I am not sure about the definition. #homework3
#homework3
DH parameters for elbow manipulato...
9:45PM
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3:03PM
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THIS WEEK
Matrix indexing and multiplication in the ...
Mon
Hi, I'm wondering if there is a way to index a matrix that you have multiplied without creating an intermediate variabl
#matlab
Private HW Drops
Mon
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DH parameters for elbow manipulator with shoulder offset
I was reading inverse kinematics in SHV and came across this robot on page 101 which has an offset on the shoulder. It seemed a useful exercise to work out its DH parameters. Can someone confirm that the parameters for the link 1 are - theta = theta1*, d = d1, alpha = -90 degrees and a = 0?
(see attached image for the co-ordinate frames I have chosen)
Oh well, my frames are wrong because x1 is supposed to intersect z0. But I can't see how to do that *and* make it perpendicular to z1.
Also, how do we account for the offset d?
#DH
Attachments:
photo.JPG
2M Open Delete Embed this image inline
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save to favorites 0
good question 0
more
11 hours ago by Samarth Manoj Brah...
4 edits
the instructors' answer, where instructors collectively construct a single answer
You must put the origin of frame 1 ant the intersection of z1 and z0, even if that point is not on the physical robot. Otherwise there is no way to write the DH parameters. The direction you chose for x1 is correct, though.
Also, check the labeling of your d1 parameter; it does not look right to me.
The value d will show up later in the DH parameter table.
edit
good answer 0
more
10 hours ago by Katherine J. Kuchenb...
2 edits
followup discussions, for lingering questions and comments
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Special Mentions:
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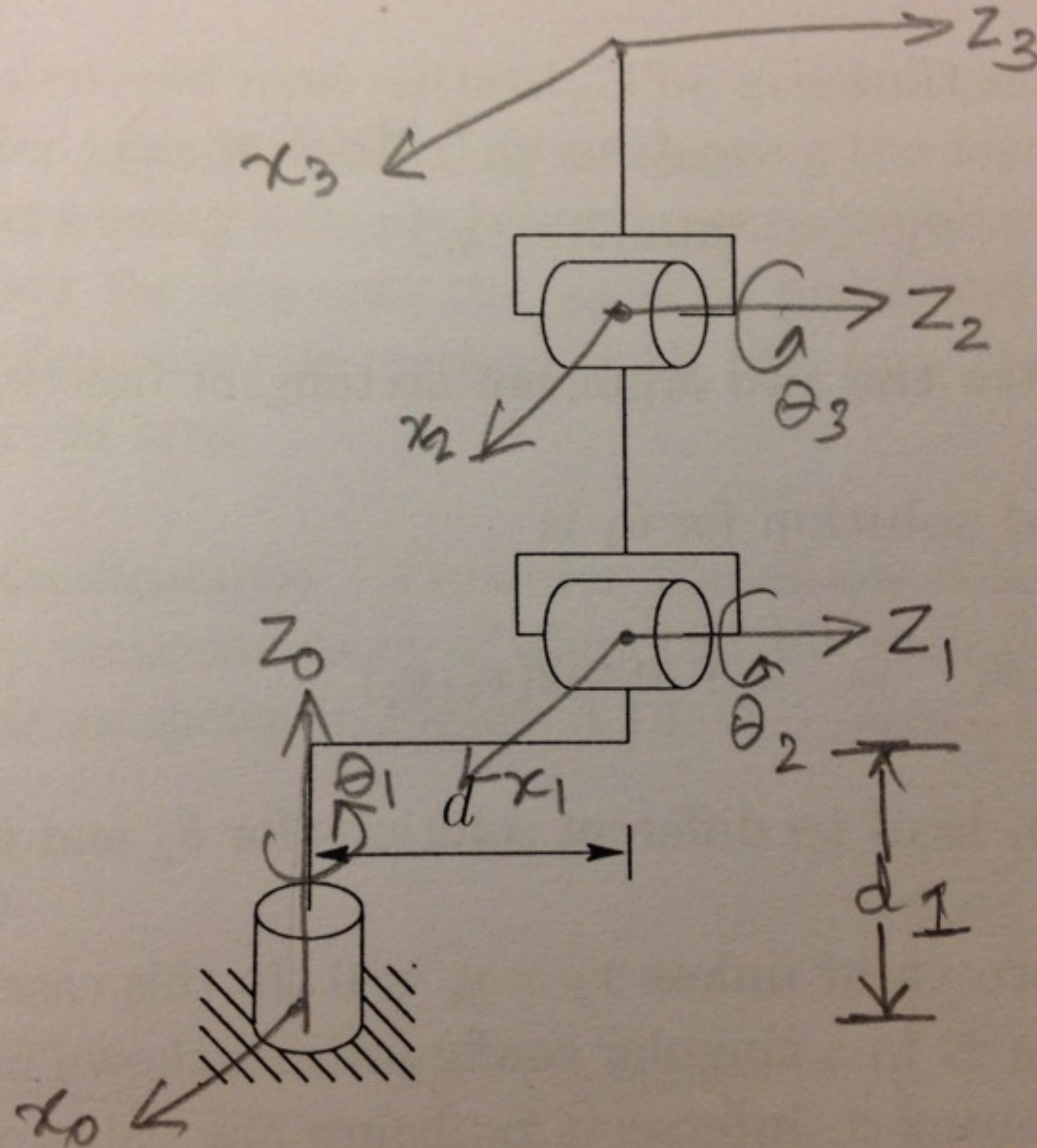


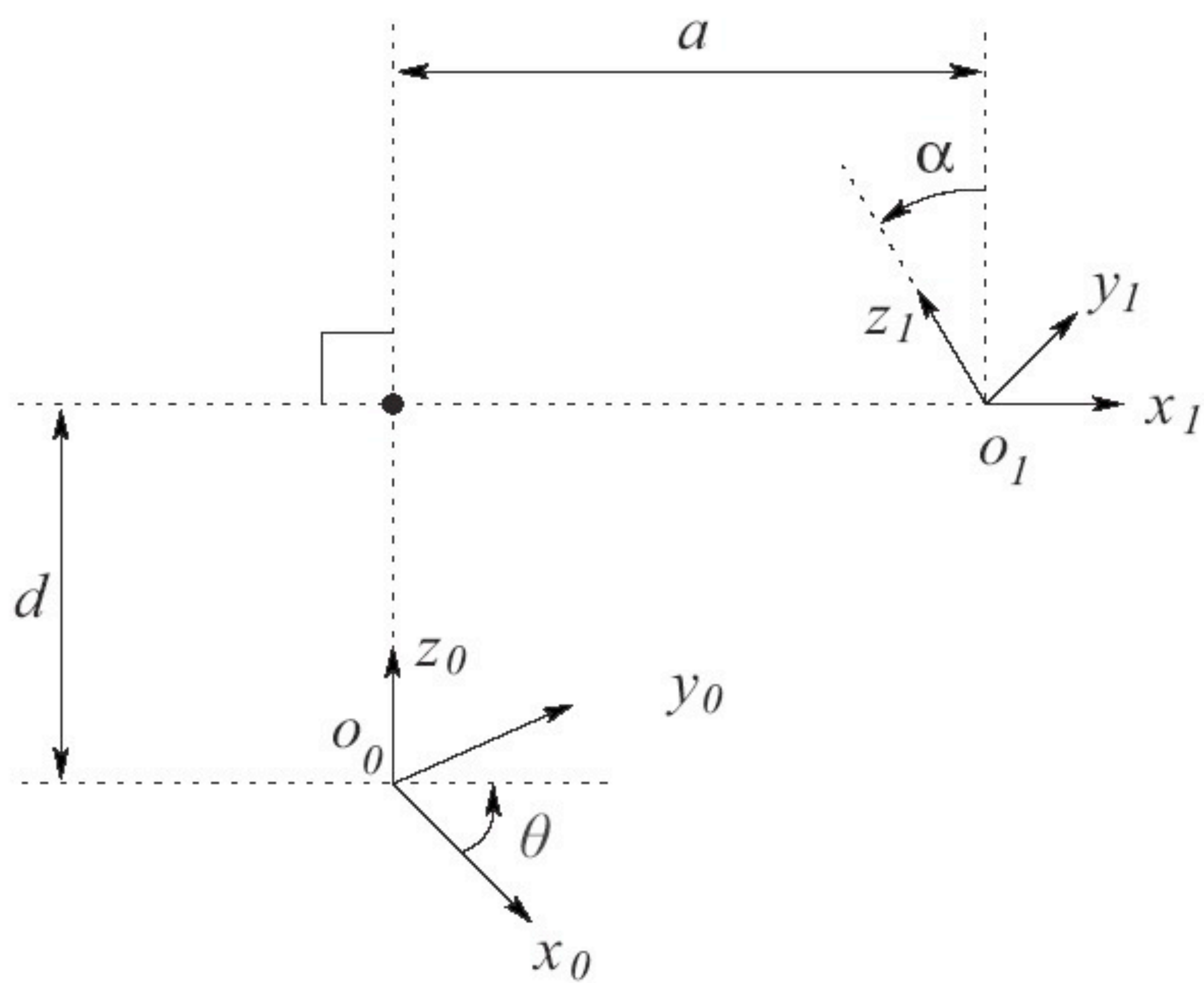
Fig. 3.16 Elbow manipulator with shoulder offset

The Denavit-Hartenberg Convention

Page 78 in SHV

(DH1) The axis x_i is perpendicular to the axis z_{i-1}

(DH2) The axis x_i intersects the axis z_{i-1}



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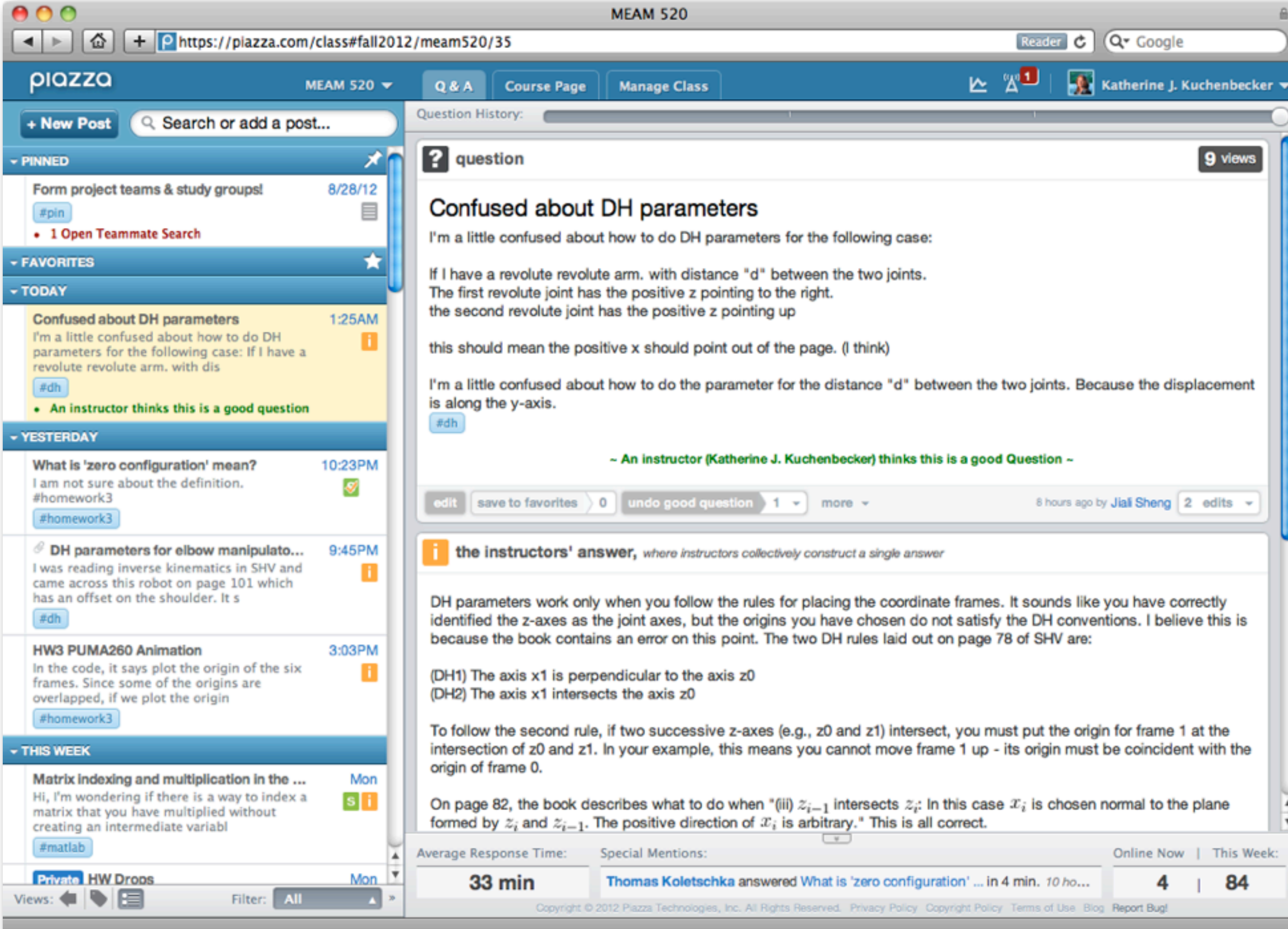
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#matlab
Private HW Drops Mon
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question
9 views
Confused about DH parameters
I'm a little confused about how to do DH parameters for the following case:
If I have a revolute revolute arm. with distance "d" between the two joints.
The first revolute joint has the positive z pointing to the right.
the second revolute joint has the positive z pointing up
this should mean the positive x should point out of the page. (I think)
I'm a little confused about how to do the parameter for the distance "d" between the two joints. Because the displacement is along the y-axis.
#dh
~ An instructor (Katherine J. Kuchenbecker) thinks this is a good Question ~
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save to favorites 0
undo good question 1
more
8 hours ago by Jiali Sheng
2 edits
the instructors' answer, where instructors collectively construct a single answer
DH parameters work only when you follow the rules for placing the coordinate frames. It sounds like you have correctly identified the z-axes as the joint axes, but the origins you have chosen do not satisfy the DH conventions. I believe this is because the book contains an error on this point. The two DH rules laid out on page 78 of SHV are:
(DH1) The axis x1 is perpendicular to the axis z0
(DH2) The axis x1 intersects the axis z0
To follow the second rule, if two successive z-axes (e.g., z0 and z1) intersect, you must put the origin for frame 1 at the intersection of z0 and z1. In your example, this means you cannot move frame 1 up - its origin must be coincident with the origin of frame 0.
On page 82, the book describes what to do when "(iii) z_{i-1} intersects z_i: In this case x_i is chosen normal to the plane formed by z_i and z_{i-1}. The positive direction of x_i is arbitrary." This is all correct.
Average Response Time:
33 min
Special Mentions:
Thomas Koletschka answered What is 'zero configuration' ... in 4 min. 10 ho...
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The Denavit-Hartenberg Convention

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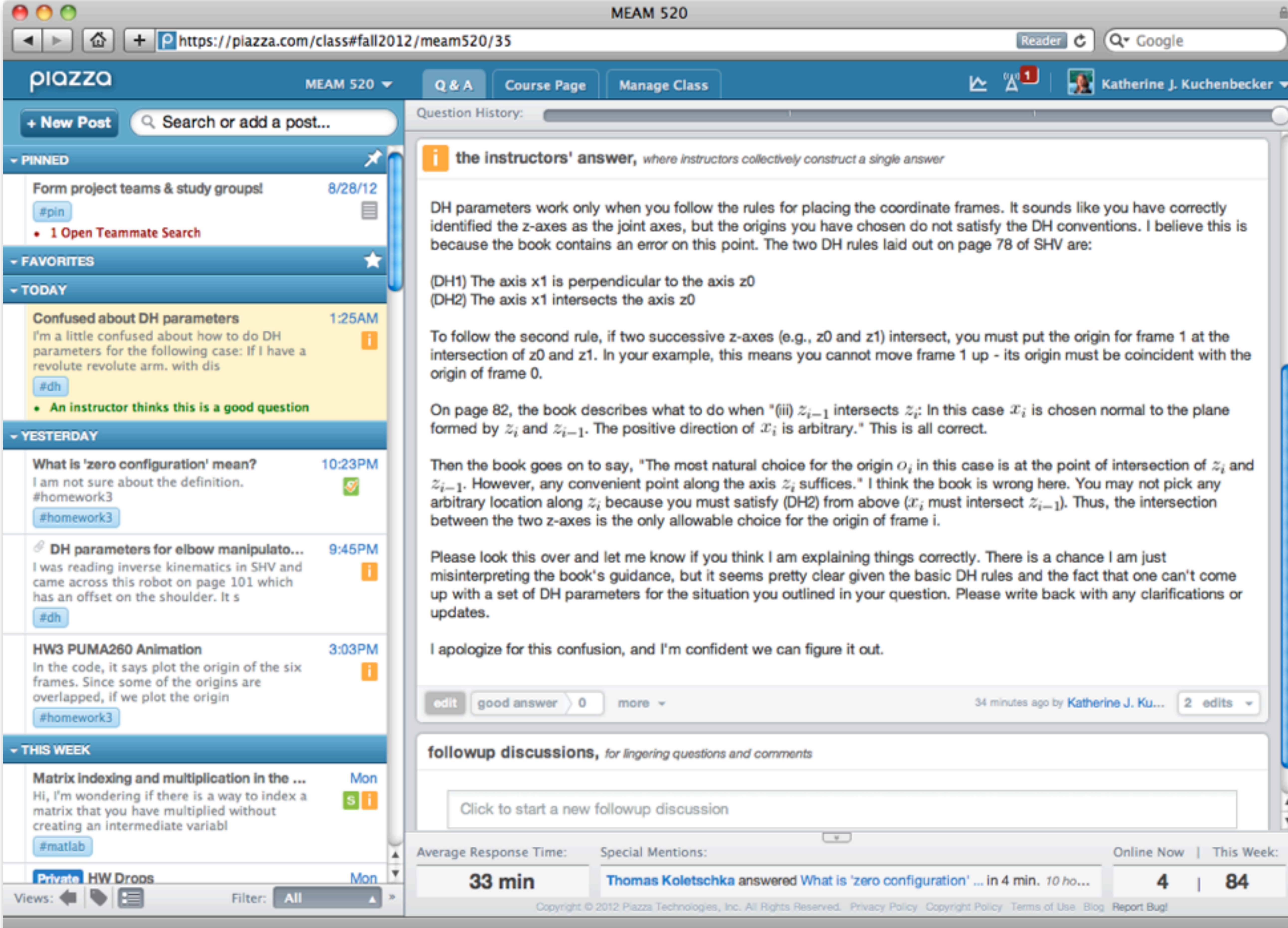
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On page 82, the book describes what to do when "(iii) z_{i-1} intersects z_i: In this case x_i is chosen normal to the plane formed by z_i and z_{i-1}. The positive direction of x_i is arbitrary." This is all correct.
Then the book goes on to say, "The most natural choice for the origin o_i in this case is at the point of intersection of z_i and z_{i-1}. However, any convenient point along the axis z_i suffices." I think the book is wrong here. You may not pick any arbitrary location along z_i because you must satisfy (DH2) from above (x_i must intersect z_{i-1}). Thus, the intersection between the two z-axes is the only allowable choice for the origin of frame i.
Please look this over and let me know if you think I am explaining things correctly. There is a chance I am just misinterpreting the book's guidance, but it seems pretty clear given the basic DH rules and the fact that one can't come up with a set of DH parameters for the situation you outlined in your question. Please write back with any clarifications or updates.
I apologize for this confusion, and I'm confident we can figure it out.
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good answer
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more
34 minutes ago by Katherine J. Ku...
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z_{i-1}, z_i are parallel. Note that in both cases (ii) and (iii) the axes z_{i-1} and z_i are coplanar. This situation is in fact quite common, as we will see in Section 3.2.3. We now consider each of these three cases.

(i) z_{i-1} and z_i are not coplanar: If z_{i-l} and z_i are not coplanar, then there exists a *unique* shortest line segment from z_{i-1} to z_i, perpendicular to both z_{i-1} to z_i. This line segment defines x_i, and the point where it intersects z_i is the origin o_i. By construction, both conditions (DH1) and (DH2) are satisfied and the vector from o_{i-1} to o_i is a linear combination of z_{i-1} and x_i. The specification of frame i is completed by choosing the axis y_i to form a right-handed frame. Since assumptions (DH1) and (DH2) are satisfied, the homogeneous transformation matrix A_i is of the form given in Equation (3.10).

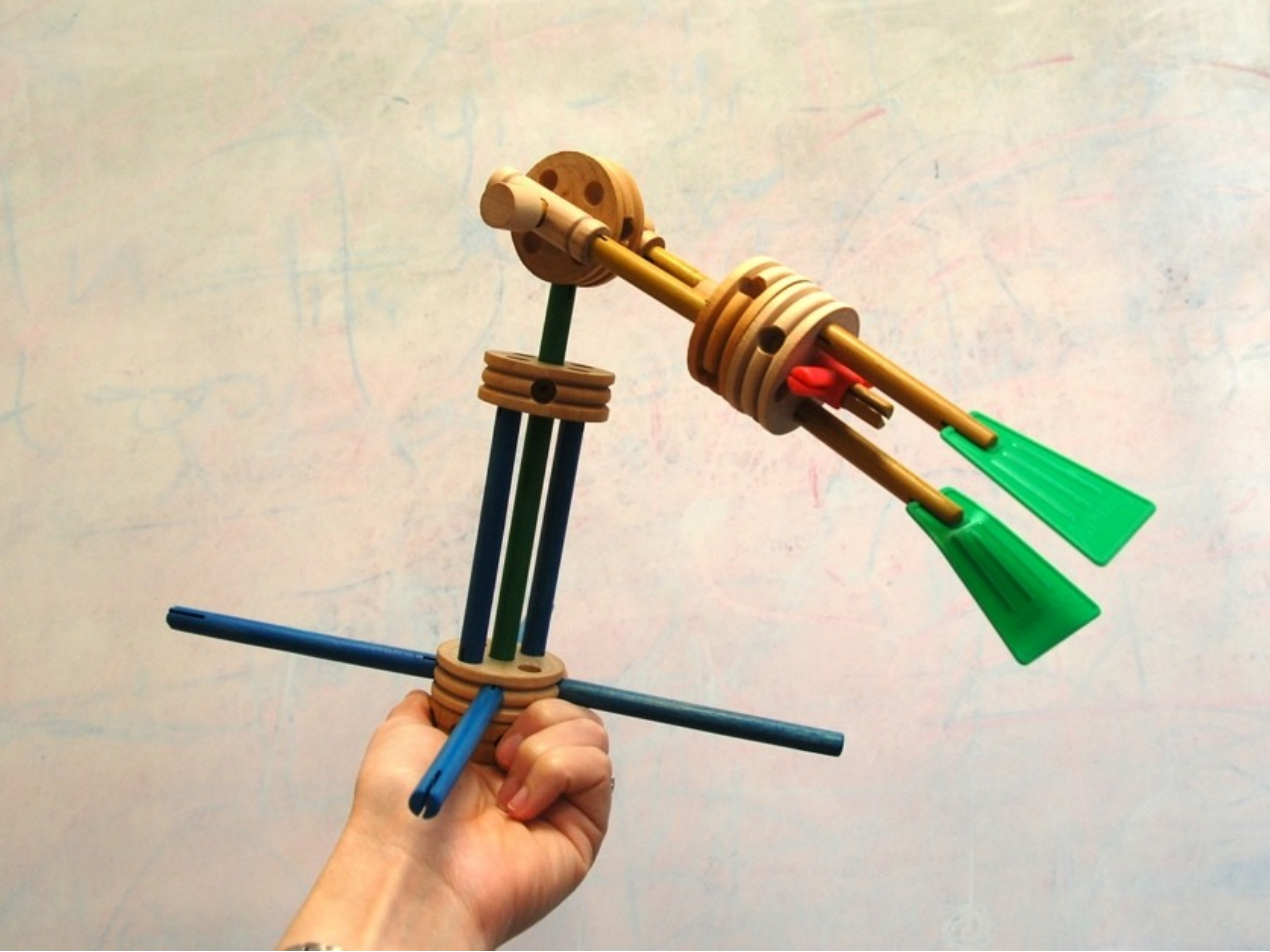
(ii) z_{i-1} is parallel to z_i: If the axes z_{i-1} and z_i are parallel, then there are infinitely many common normals between them and condition (DH1) does not specify x_i completely. In this case we are free to choose the origin o_i anywhere along z_i. One often chooses o_i to simplify the resulting equations. The axis x_i is then chosen either to be directed from o_i toward z_{i-1}, along the common normal, or as the opposite of this vector. A common method for choosing o_i is to choose the normal that passes through o_{i-1} as the x_i axis; o_i is then the point at which this normal intersects z_i. In this case, d_i would be equal to zero. Once x_i is fixed, y_i is determined, as usual by the right hand rule. Since the axes z_{i-1} and z_i are parallel, α_i will be zero in this case.

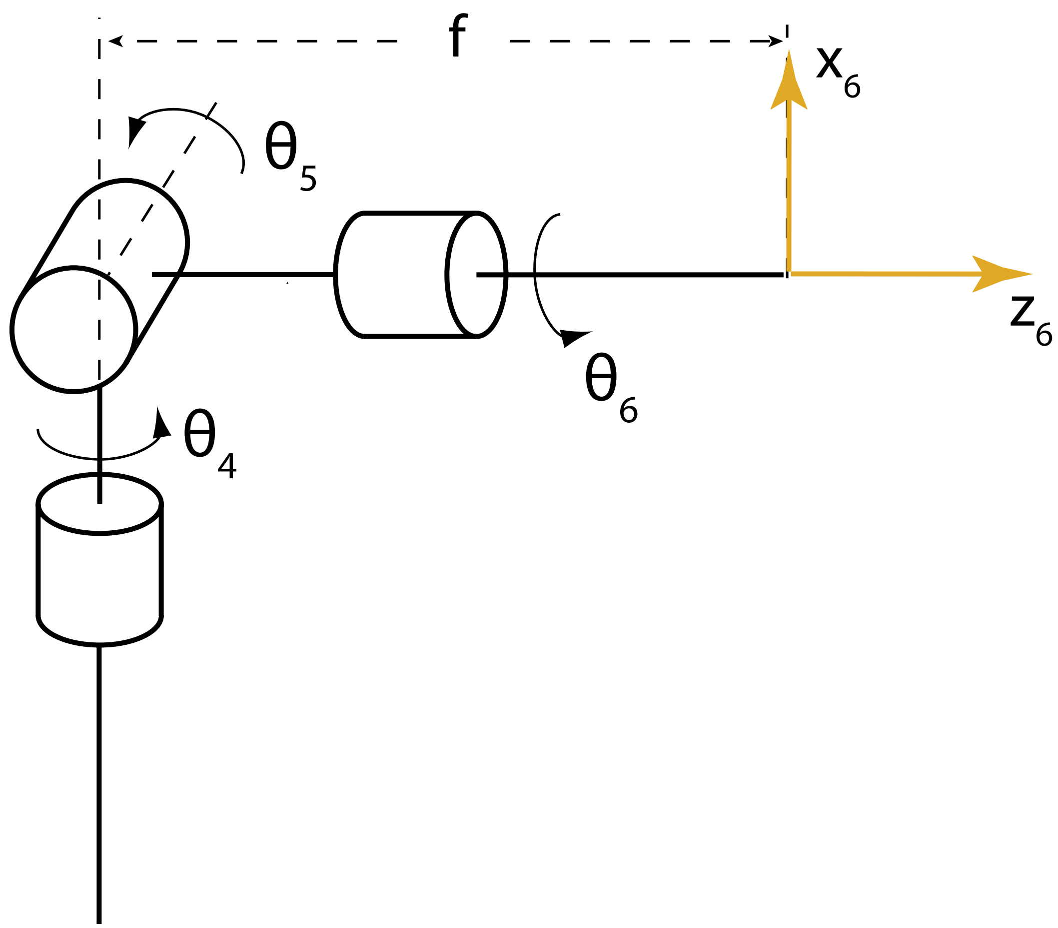
(iii) z_{i-1} intersects z_i: In this case x_i is chosen normal to the plane formed by z_i and z_{i-1}. The positive direction of x_i is arbitrary. The ~~most~~ only ~~natural~~ choice for the origin o_i in this case is at the point of intersection of z_i and z_{i-1}. ~~However, any convenient point along the axis z_i suffices.~~ Note that in this case the parameter a_i will be zero.

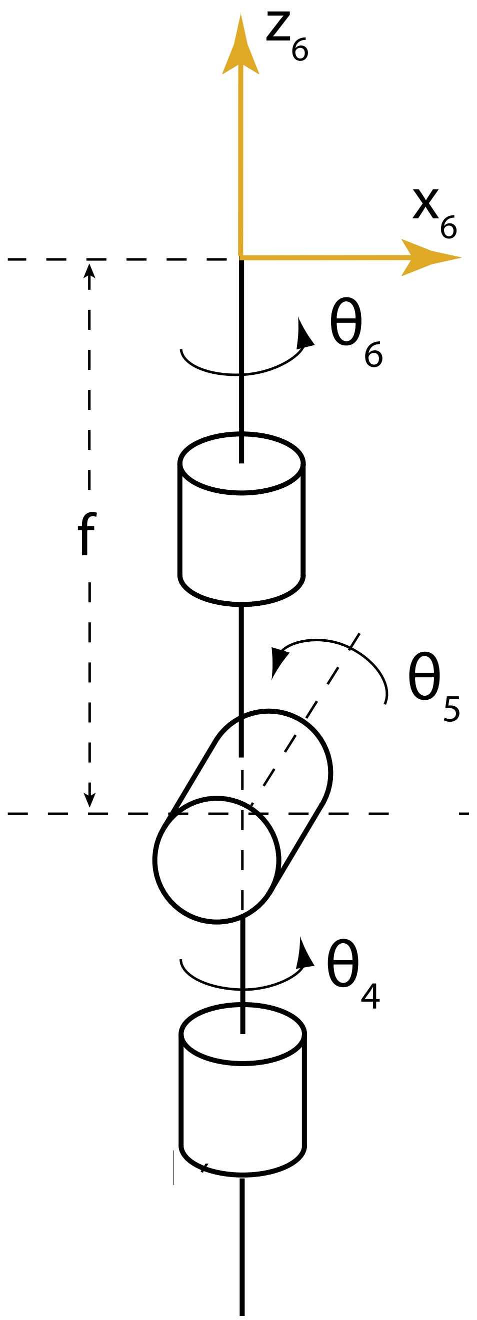
This constructive procedure works for frames $0, \ldots, n-1$ in an n-link robot. To complete the construction it is necessary to specify frame n. The final coordinate system $o_n x_n y_n z_n$ is commonly referred to as the **end effector** or **tool frame** (see Figure 3.5). The origin o_n is most often placed symmetrically between the fingers of the gripper. The unit vectors along the x_n, y_n, and z_n axes are labeled as n, s, and a, respectively. The terminology arises from the fact that the direction a is the **approach** direction, in the sense that the gripper typically approaches an object along the a direction. Similarly the s direction is the **sliding** direction, the direction along which

Questions ❓

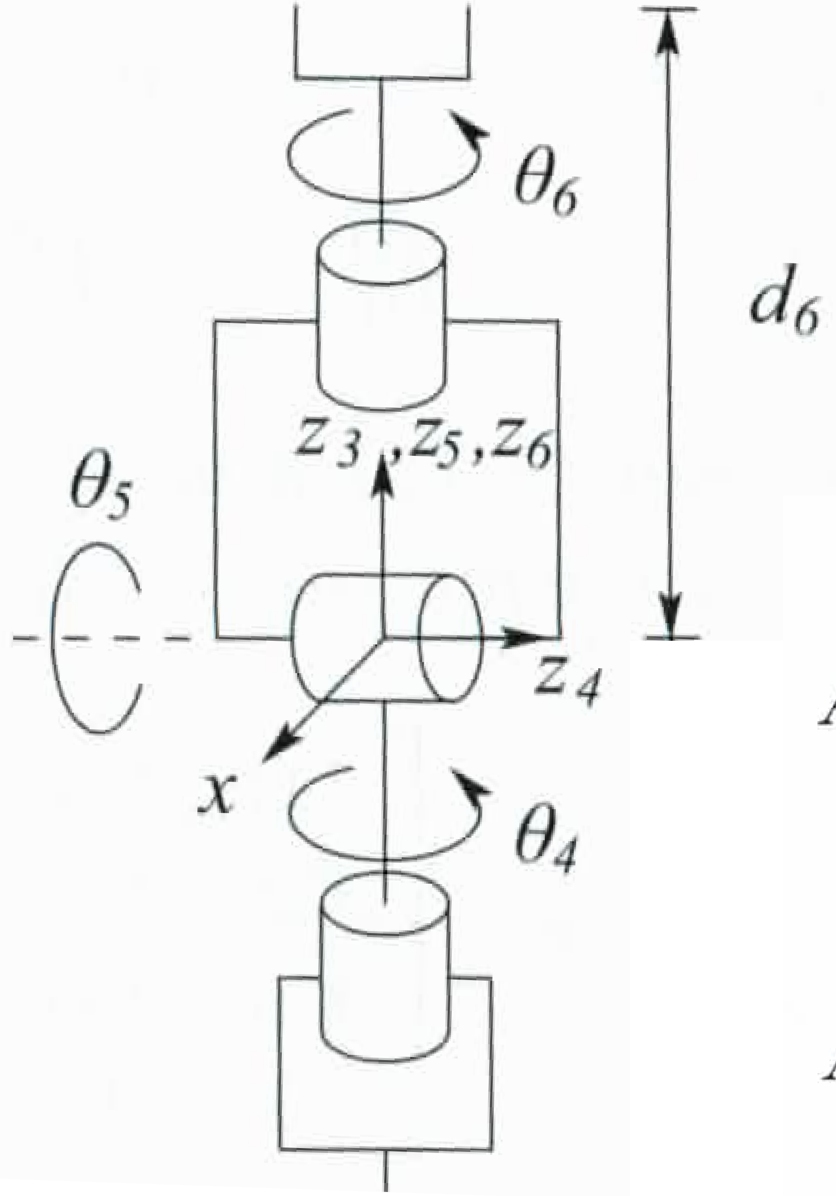
Inverse Orientation Kinematics




f
x_6
z_6
θ_5
θ_6
θ_4


z_6
x_6
θ_6
f
θ_5
θ_4

Given rotation matrix **R**, find the joint angles that put the end-effector in the desired orientation.



Link	a_i	α_i	d_i	θ_i
4	0	−90	0	θ_4^*
5	0	90	0	θ_5^*
6	0	0	d_6	θ_6^*

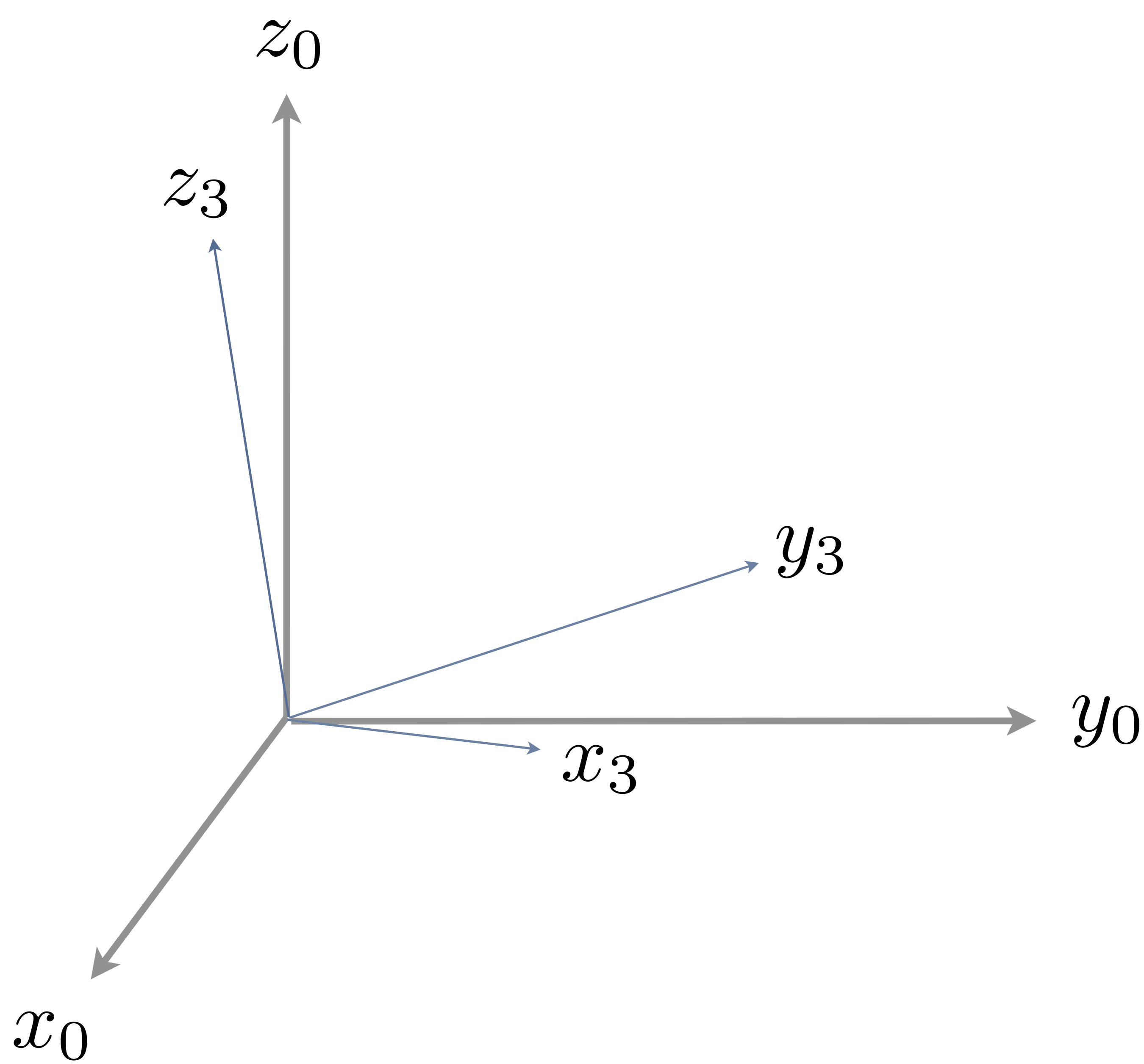
$$A_4 = \begin{bmatrix} c_4 & 0 & -s_4 & 0 \\ s_4 & 0 & c_4 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad A_5 = \begin{bmatrix} c_5 & 0 & s_5 & 0 \\ s_5 & 0 & -c_5 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$A_6 = \begin{bmatrix} c_6 & -s_6 & 0 & 0 \\ s_6 & c_6 & 0 & 0 \\ 0 & 0 & 1 & d_6 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

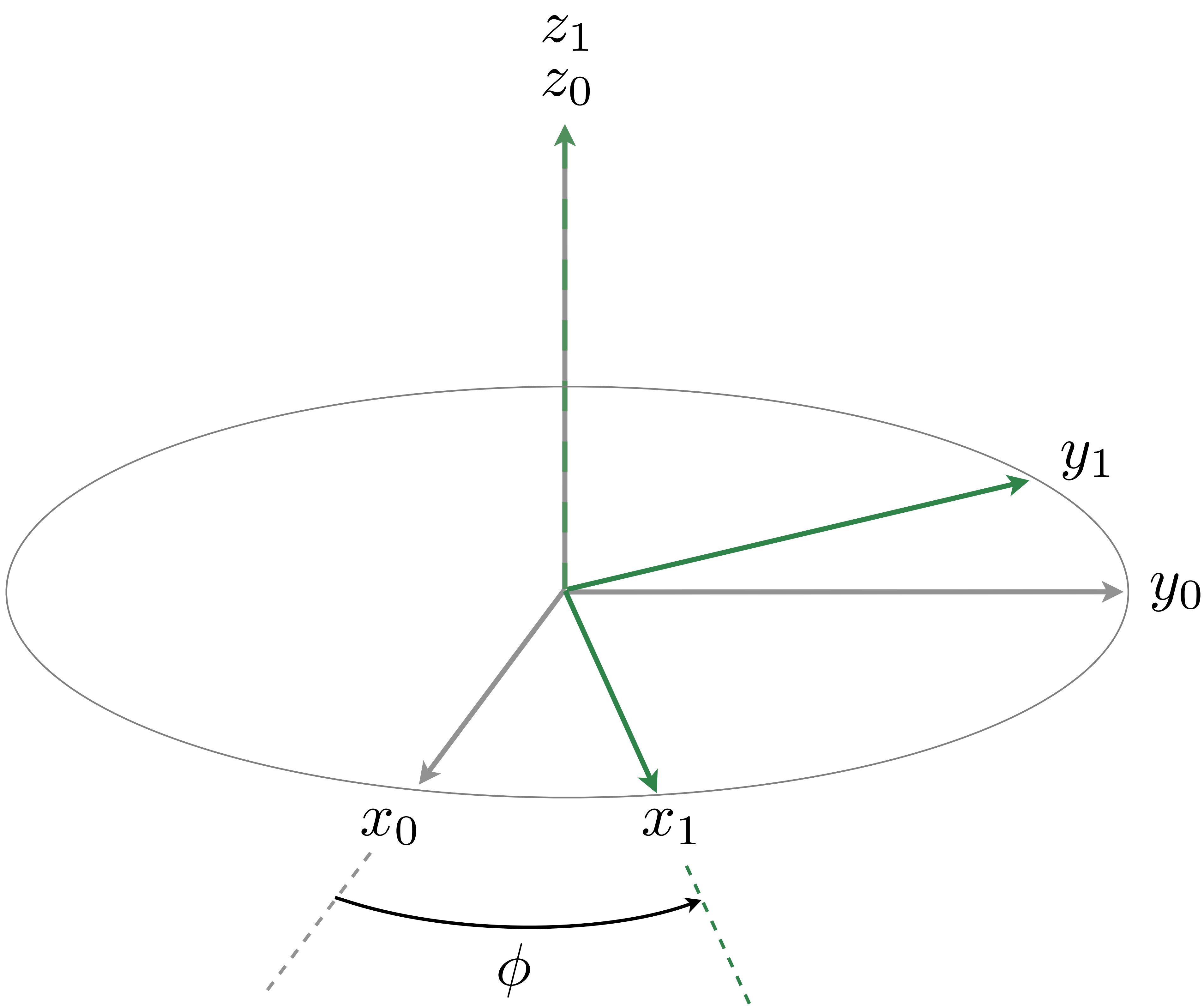
$$\begin{aligned} T_6^3 &= A_4 A_5 A_6 \\ &= \begin{bmatrix} R_6^3 & o_6^3 \\ 0 & 1 \end{bmatrix} \\ &= \begin{bmatrix} c_4c_5c_6 - s_4s_6 & -c_4c_5s_6 - s_4c_6 & c_4s_5 & c_4s_5d_6 \\ s_4c_5c_6 + c_4s_6 & -s_4c_5s_6 + c_4c_6 & s_4s_5 & s_4s_5d_6 \\ -s_5c_6 & s_5s_6 & c_5 & c_5d_6 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{aligned}$$

Euler Angles

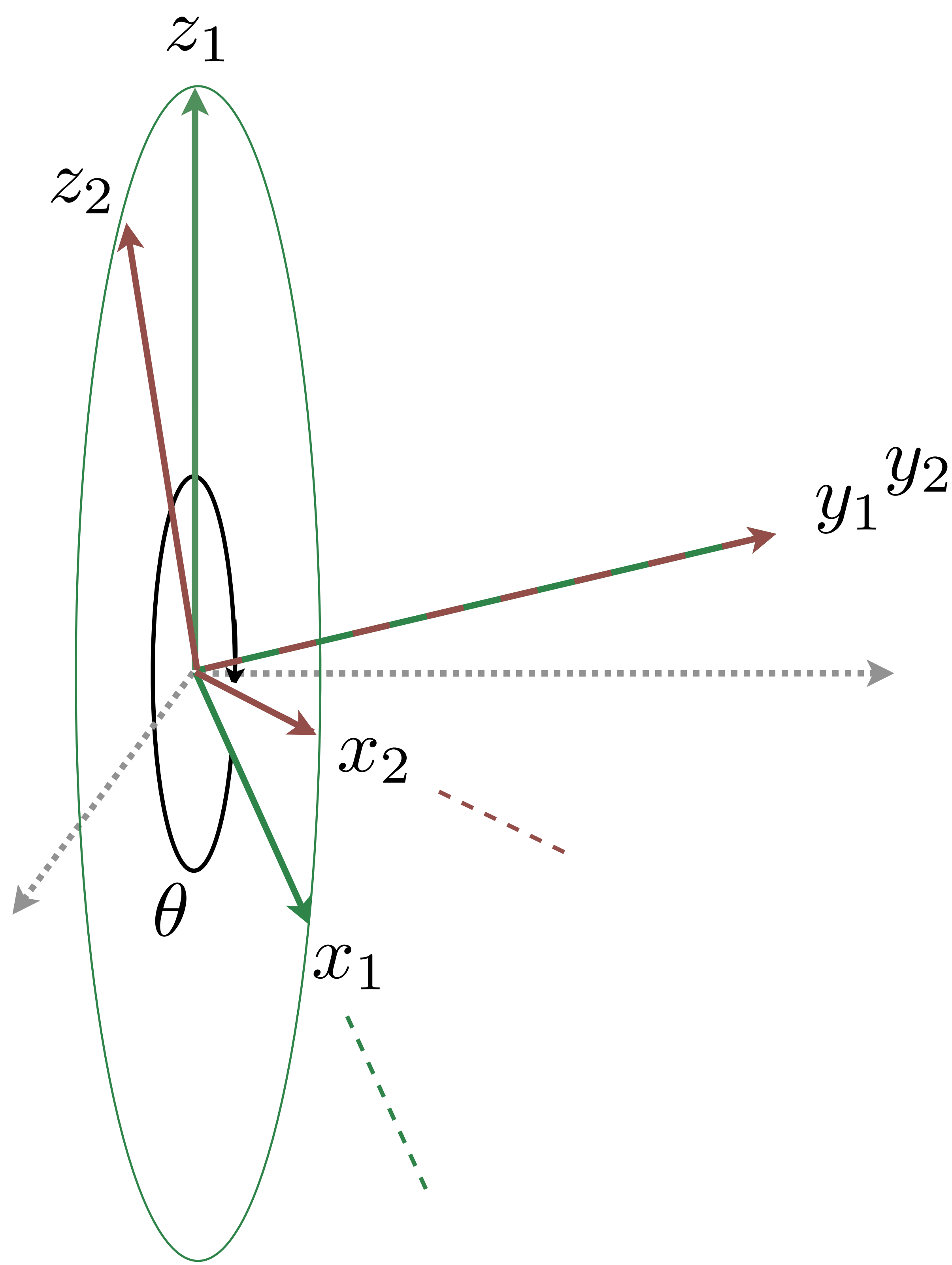
Define a set of three **intermediate** angles, ϕ, θ, ψ , to go from $0 \rightarrow 3$



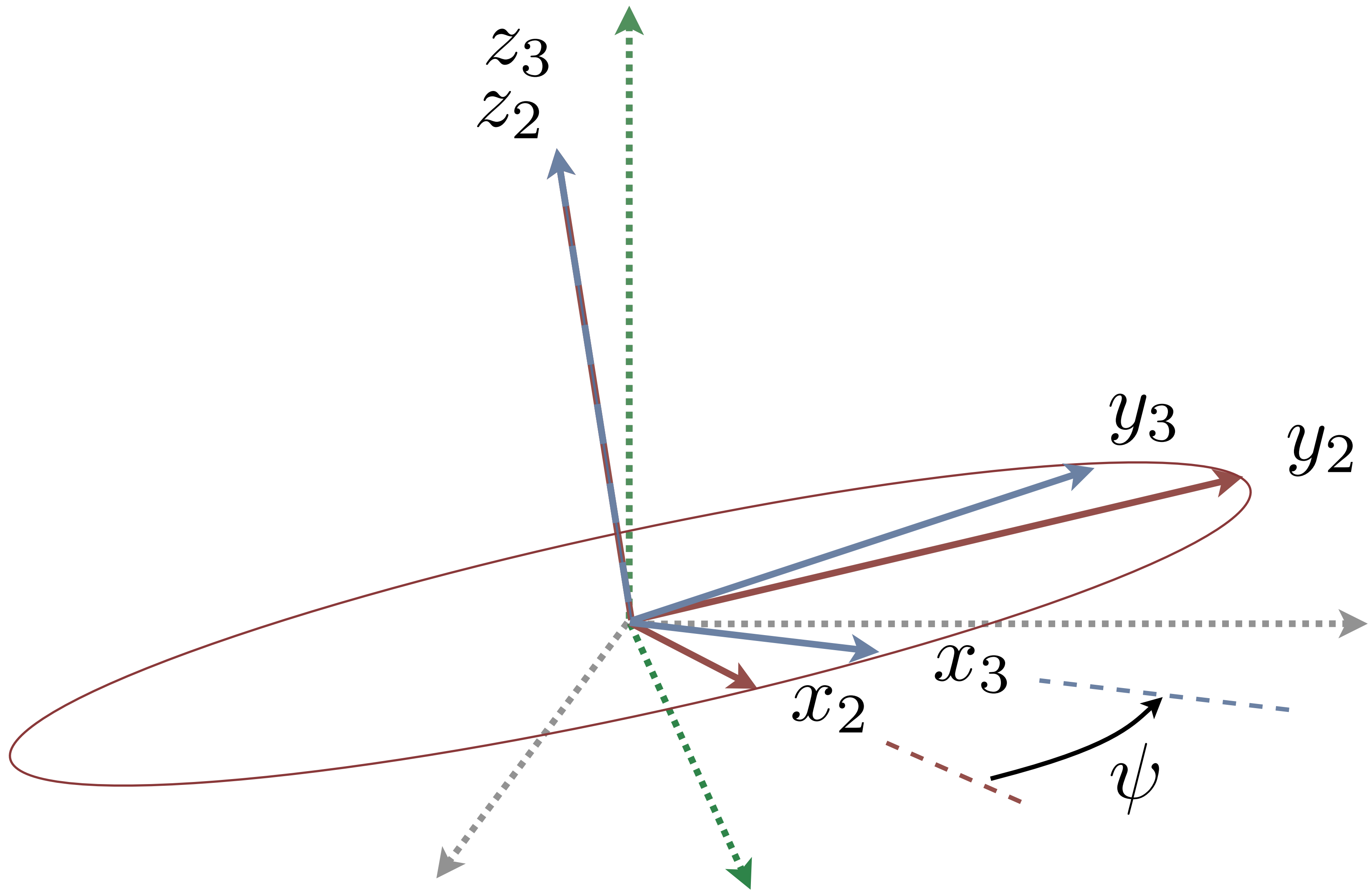
step 1: rotate by ϕ about z_0



step 2: rotate by θ about y_1



step 3: rotate by ψ about z_2



Euler Angles to Rotation Matrices

(**post**-multiply using the **basic rotation matrices**)

$$\mathbf{R} = \mathbf{R}_{z,\phi}\, \mathbf{R}_{y,\theta}\, \mathbf{R}_{z,\psi}$$

$$= \begin{bmatrix} c_\phi & -s_\phi & 0 \\ s_\phi & c_\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} c_\theta & 0 & s_\theta \\ 0 & 1 & 0 \\ -s_\theta & 0 & c_\theta \end{bmatrix} \begin{bmatrix} c_\psi & -s_\psi & 0 \\ s_\psi & c_\psi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} c_\phi c_\theta c_\psi - s_\phi s_\psi & -c_\phi c_\theta s_\psi - s_\phi c_\psi & c_\phi s_\theta \\ s_\phi c_\theta c_\psi + c_\phi s_\psi & -s_\phi c_\theta s_\psi + c_\phi c_\psi & s_\phi s_\theta \\ -s_\theta c_\psi & s_\theta s_\psi & c_\theta \end{bmatrix}$$

$$
\begin{aligned}
T_6^3 &= A_4 A_5 A_6 \\
&= \begin{bmatrix} R_6^3 & o_6^3 \\ 0 & 1 \end{bmatrix} \\
&= \begin{bmatrix} c_4c_5c_6 - s_4s_6 & -c_4c_5s_6 - s_4c_6 & c_4s_5 & c_4s_5d_6 \\ s_4c_5c_6 + c_4s_6 & -s_4c_5s_6 + c_4c_6 & s_4s_5 & s_4s_5d_6 \\ -s_5c_6 & s_5s_6 & c_5 & c_5d_6 \\ 0 & 0 & 0 & 1 \end{bmatrix}
\end{aligned}
$$

$$\theta_4 = \phi \qquad \theta_5 = \theta \qquad \theta_6 = \psi$$

$$
= \begin{bmatrix} c_\phi c_\theta c_\psi - s_\phi s_\psi & -c_\phi c_\theta s_\psi - s_\phi c_\psi & c_\phi s_\theta \\ s_\phi c_\theta c_\psi + c_\phi s_\psi & -s_\phi c_\theta s_\psi + c_\phi c_\psi & s_\phi s_\theta \\ -s_\theta c_\psi & s_\theta s_\psi & c_\theta \end{bmatrix}
$$

The book explains how to calculate the three angles given **R**: see SHV pages 55-56

To find a solution for this problem we break it down into two cases. First, suppose that not both of r_{13}, r_{23} are zero. Then from Equation (2.26) we deduce that $s_\theta \neq 0$, and hence that not both of r_{31}, r_{32} are zero. If not both r_{13} and r_{23} are zero, then $r_{33} \neq \pm 1$, and we have $c_\theta = r_{33}$, $s_\theta = \pm\sqrt{1 - r_{33}^2}$ so

$$\theta = \mathrm{Atan2}\left(r_{33}, \sqrt{1 - r_{33}^2}\right) \tag{2.28}$$

or

$$\theta = \mathrm{Atan2}\left(r_{33}, -\sqrt{1 - r_{33}^2}\right) \tag{2.29}$$

where the function Atan2 is the **two-argument arctangent function** defined in Appendix A.

If we choose the value for θ given by Equation (2.28), then $s_\theta > 0$, and

$$\phi = \mathrm{Atan2}(r_{13}, r_{23}) \tag{2.30}$$
$$\psi = \mathrm{Atan2}(-r_{31}, r_{32}) \tag{2.31}$$

If we choose the value for θ given by Equation (2.29), then $s_\theta < 0$, and

$$\phi = \mathrm{Atan2}(-r_{13}, -r_{23}) \tag{2.32}$$
$$\psi = \mathrm{Atan2}(r_{31}, -r_{32}) \tag{2.33}$$

Thus, there are two solutions depending on the sign chosen for θ.

If $r_{13} = r_{23} = 0$, then the fact that R is orthogonal implies that $r_{33} = \pm 1$, and that $r_{31} = r_{32} = 0$. Thus, R has the form

$$R = \begin{bmatrix} r_{11} & r_{12} & 0 \\ r_{21} & r_{22} & 0 \\ 0 & 0 & \pm 1 \end{bmatrix} \tag{2.34}$$

If $r_{33} = 1$, then $c_\theta = 1$ and $s_\theta = 0$, so that $\theta = 0$. In this case, Equation (2.26) becomes

$$\begin{bmatrix} c_\phi c_\psi - s_\phi s_\psi & -c_\phi s_\psi - s_\phi c_\psi & 0 \\ s_\phi c_\psi + c_\phi s_\psi & -s_\phi s_\psi + c_\phi c_\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} c_{\phi+\psi} & -s_{\phi+\psi} & 0 \\ s_{\phi+\psi} & c_{\phi+\psi} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Thus, the sum $\phi + \psi$ can be determined as

$$\phi + \psi = \mathrm{Atan2}(r_{11}, r_{21}) = \mathrm{Atan2}(r_{11}, -r_{12}) \tag{2.35}$$

Since only the sum $\phi + \psi$ can be determined in this case, there are infinitely many solutions. In this case, we may take $\phi = 0$ by convention. If $r_{33} = -1$, then $c_\theta = -1$ and $s_\theta = 0$, so that $\theta = \pi$. In this case Equation (2.26) becomes

$$\begin{bmatrix} -c_{\phi-\psi} & -s_{\phi-\psi} & 0 \\ s_{\phi-\psi} & c_{\phi-\psi} & 0 \\ 0 & 0 & -1 \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & 0 \\ r_{21} & r_{22} & 0 \\ 0 & 0 & -1 \end{bmatrix} \tag{2.36}$$

The solution is thus

$$\phi - \psi = \mathrm{Atan2}(-r_{11}, -r_{12}) \tag{2.37}$$

As before there are infinitely many solutions.

2.5.2 Roll, Pitch, Yaw Angles

A rotation matrix R can also be described as a product of successive rotations about the principal coordinate axes x_0, y_0, and z_0 taken in a specific order. These rotations define the **roll**, **pitch**, and **yaw** angles, which we shall also denote ϕ, θ, ψ, and which are shown in Figure 2.11.

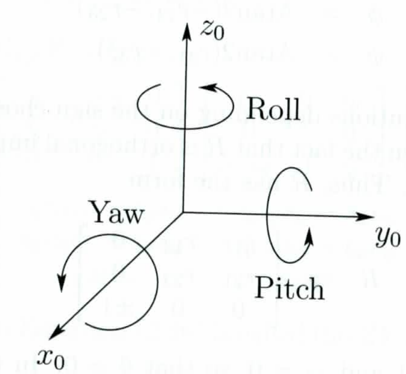


Figure 2.11: Roll, pitch, and yaw angles.

We specify the order of rotation as $x - y - z$, in other words, first a yaw about x_0 through an angle ψ, then pitch about the y_0 by an angle θ, and finally roll about the z_0 by an angle ϕ.[4] Since the successive rotations are

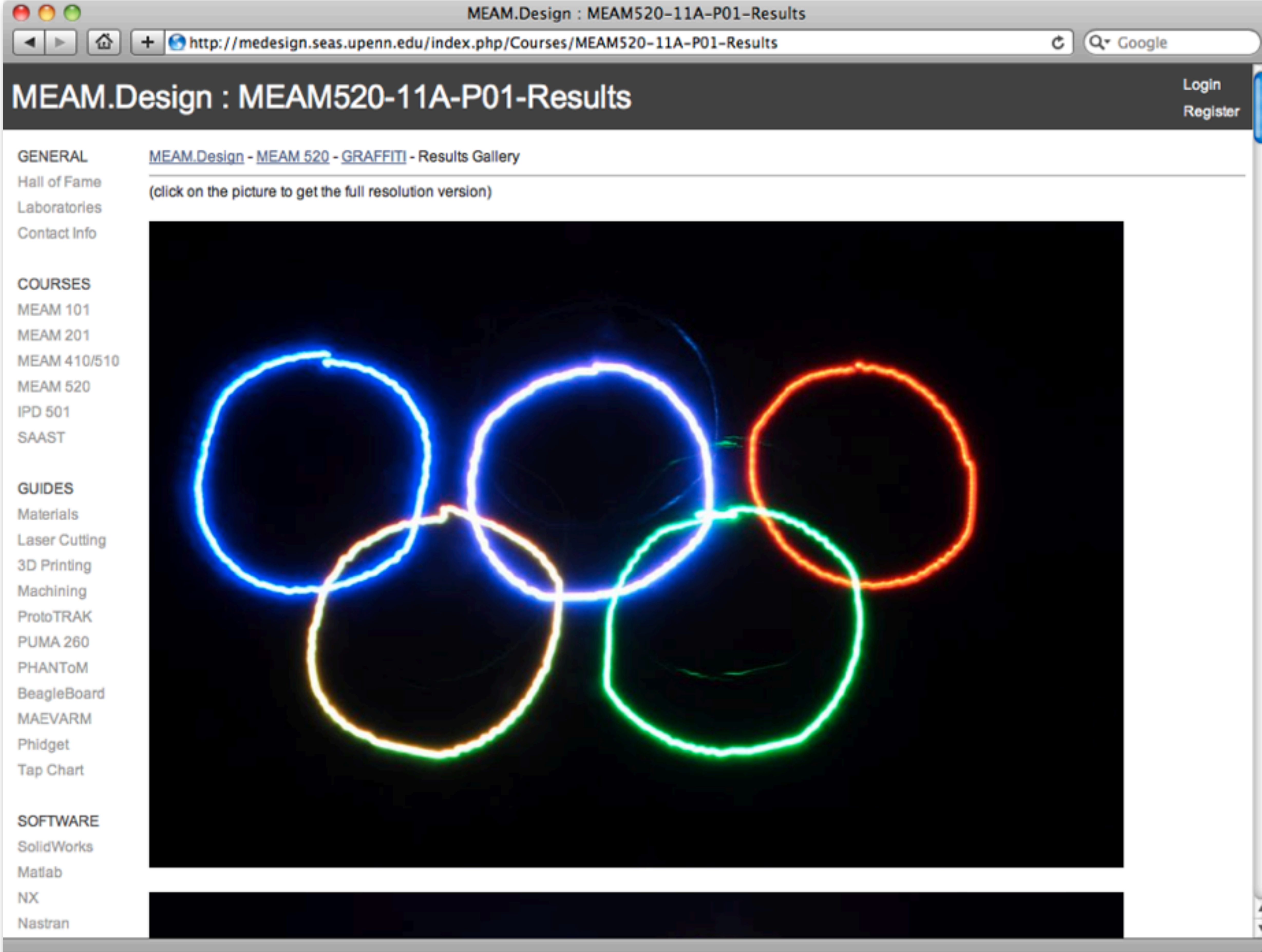
[4]It should be noted that other conventions exist for naming the roll, pitch, and yaw angles.

Questions ?

Project 1

Light Painting with the Puma 260

- The Puma 260 has been equipped with a tri-color LED end-effector.
- Taking long-exposure photos of the Puma moving in a darkened room produces works of art known as “light paintings.”
- Your job is to work in a team of three to create a beautiful Puma light painting.


MEAM.Design : MEAM520-11A-P01-Results
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IPD 501
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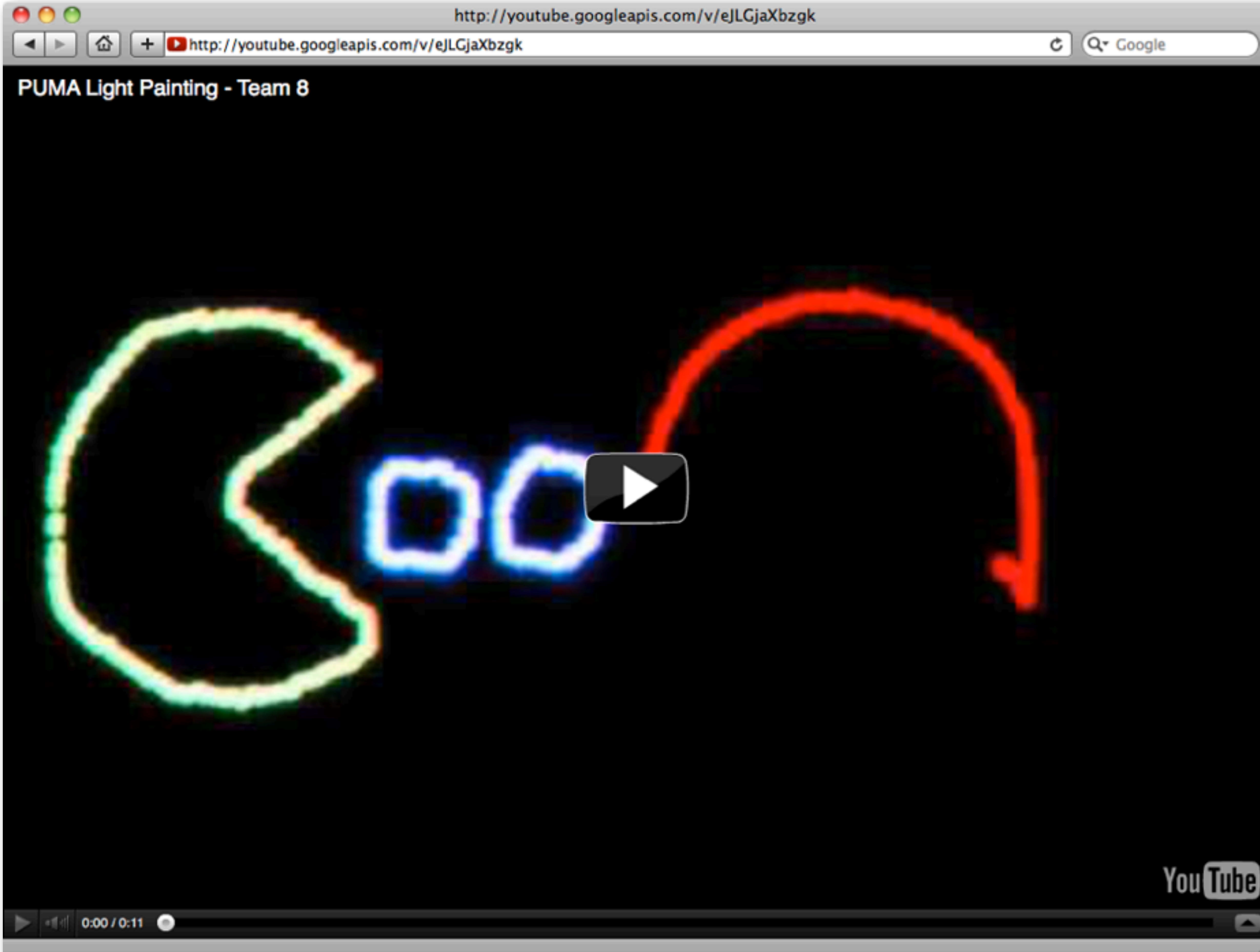
GUIDES
Materials
Laser Cutting
3D Printing
Machining
ProtoTRAK
PUMA 260
PHANToM
BeagleBoard
MAEVARM
Phidget
Tap Chart
SOFTWARE
SolidWorks
Matlab
NX
Nastran
MEAM.Design - MEAM 520 - GRAFFITI - Results Gallery
(click on the picture to get the full resolution version)


http://youtube.googleapis.com/v/eJLGjaXbzgk
http://youtube.googleapis.com/v/eJLGjaXbzgk
Google
PUMA Light Painting - Team 8
YouTube
0:00 / 0:11

What knowledge do you need to do this project?

Unimation

PUMA 260

Slides created by
Jonathan Fiene

May 1984
New Information
Mailed To: E, C, D/22-505A, C, E

A compact, computer-controlled robot for high speed, close-tolerance assembly, light materials handling, and inspection applications.

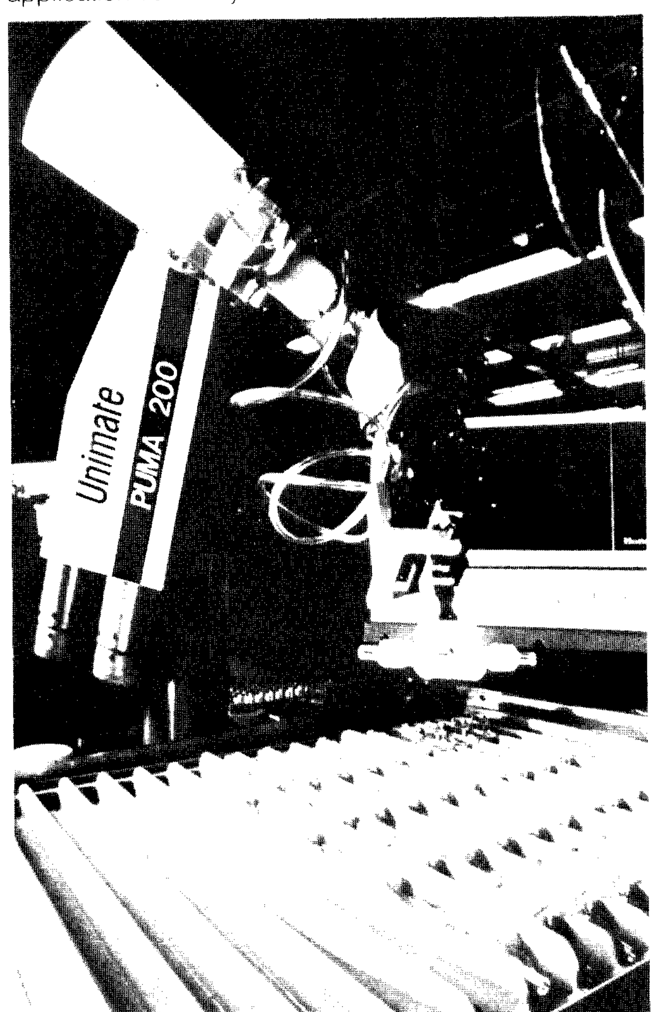
UNIMATE® PUMA® Series 200 Industrial Robot

FEATURES

The Series 200 is the most compact model in the UNIMATE PUMA line of electrically driven industrial robots. With an 18-inch reach and 2.2-pound payload capacity, the PUMA Series 200 robot is designed for medium to high-speed assembly and materials handling applications. Its capabilities are particularly suited to the requirements of electronics and other industries where lightweight parts handling is highly repetitive, fast and precise.

EASE OF USE

VAL™ a revolutionary advance in robot control systems, is used to control and program PUMA robots. The system uses an LSI-11 as a central processing unit and communicates with individual joint processors for servo control of robot arm motions. The results are ease in set up, high-tolerance repeatability, and greater application versatility.



VAL combines a sophisticated, easy to use robot programming capability with advanced servo control methods. Intuitive English language instruction provides fast, efficient program generation and editing capabilities. All servo-path computations are performed in real time, which makes it possible to interface with sensory-based systems.

EASE OF INSTALLATION

PUMA 200 robots are easily integrated into existing production lines because of the ease with which they are programmed. In addition, the robot can be easily and quickly reprogrammed for changes in the product or production process.

Programs can be written either on- or off-line using a CRT or teletype terminal, or they can be generated manually by guiding the robot arm through program paths using a microprocessor-based teach pendant. With either method, position data can be added or changed by key input, manual control or floppy disk input without affecting the overall task program.

VAL reduces memory requirements and permits complex programs, such as palletizing routines, to be easily written with a minimum number of taught positions.

Significant time savings can also be realized by integrating predefined subroutines and tasks into complex operations. These tasks can also be stored on floppy disks to build a library of routines, and even whole programs, that can be loaded into the memory of any PUMA controller so that specific tasks and repetitive routines need to be written only once.

With VAL, the Series 200 can also respond to fluctuations in the rate or other parameters of on-going production processes. Since all servo-path computations are performed in real time, changes in the arm path, or even task sequencing, can be initiated by feedback from various sensors and vision systems. As a result, the 200 can interact flexibly and efficiently as part of a large and complex manufacturing system.

APPLICATIONS

With its high speed, repeatability, and flexibility the PUMA 200 robot is suited to a wide range of small parts-handling applications, and VAL control makes it easy to design application programs to carry out the most difficult robotic tasks.

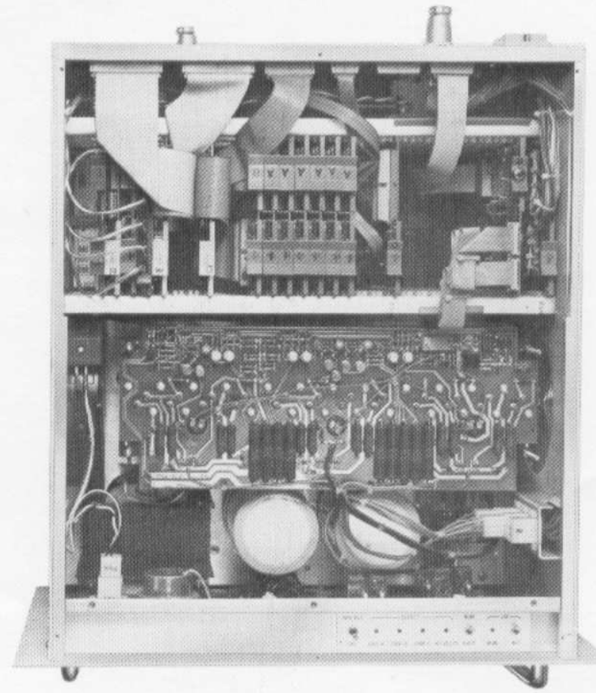
Current assembly applications include automotive instrument panels, small electric motors, printed circuit boards, subassemblies for radios, television sets, appliances and more. Other applications include packaging functions in the pharmaceutical, personal care, and food industries. Palletizing of small parts, inspection, and electronic parts handling in the computer, aerospace and defense industries round out the present installed base.

ADVANCED ENGINEERING

Modular, straightforward layout facilitating easy board replacement and plug-in expansion.

High-volume ventilation system.

Digital servo components designed for high-temperature operation and state-of-art dc motor control.



Compact packaging (19 in. rack mountable.).

Power amplifiers designed for high energy output with sensors for high temperature.

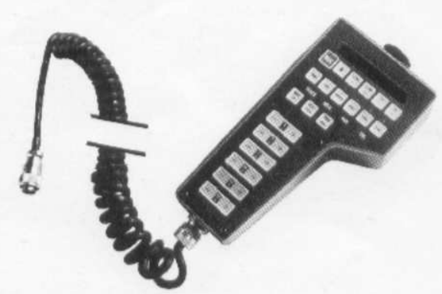
Auto-start button for automatic operation.

Easy-access panel location for self-diagnostic indicators and troubleshooting switches.

High-density, double-sided floppy-disk drive unit for program storage at 9,600 baud with 10,000-hour MTBF componentry.

Durable, industrially hardened design utilizing monocoque construction for stiff, accurate motions.

Servo motors incorporating square wave encoders offer the most proven and sophisticated drive systems.



Industrial-grade, membrane-type teach pendant and CRT.

High-precision gearing designed for ultra-low backlash and specially hardened for long life.

Unimate®

PUMA® Mark II Robot

200 Series Equipment Manual for VAL™ II and VAL™ PLUS Operating Systems

398V1

Unimation

A Westinghouse Company

Unimation Incorporated
Shelter Rock Lane
Danbury, Connecticut 06810

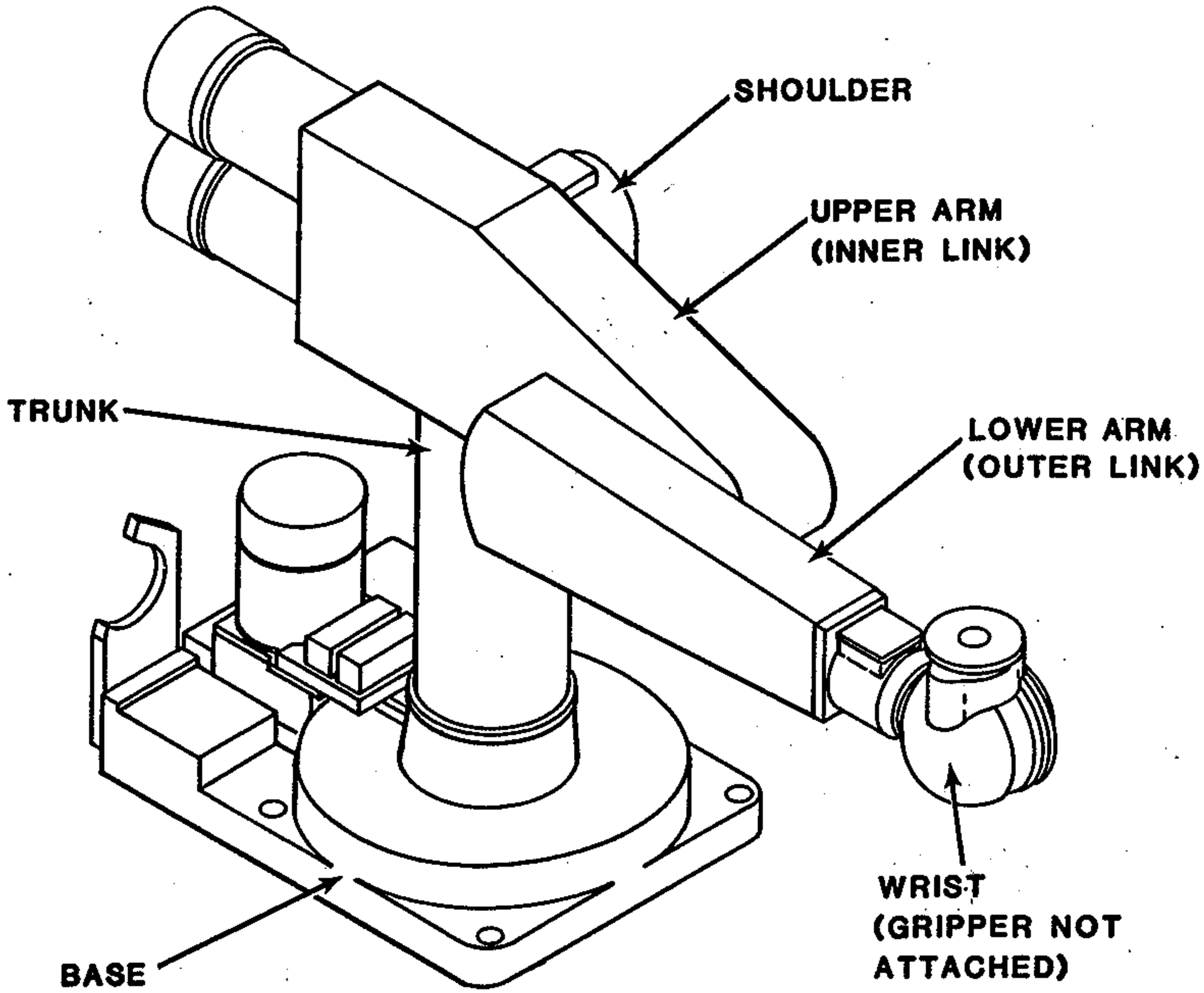


Figure 1-14. A Typical Video Terminal: CRT

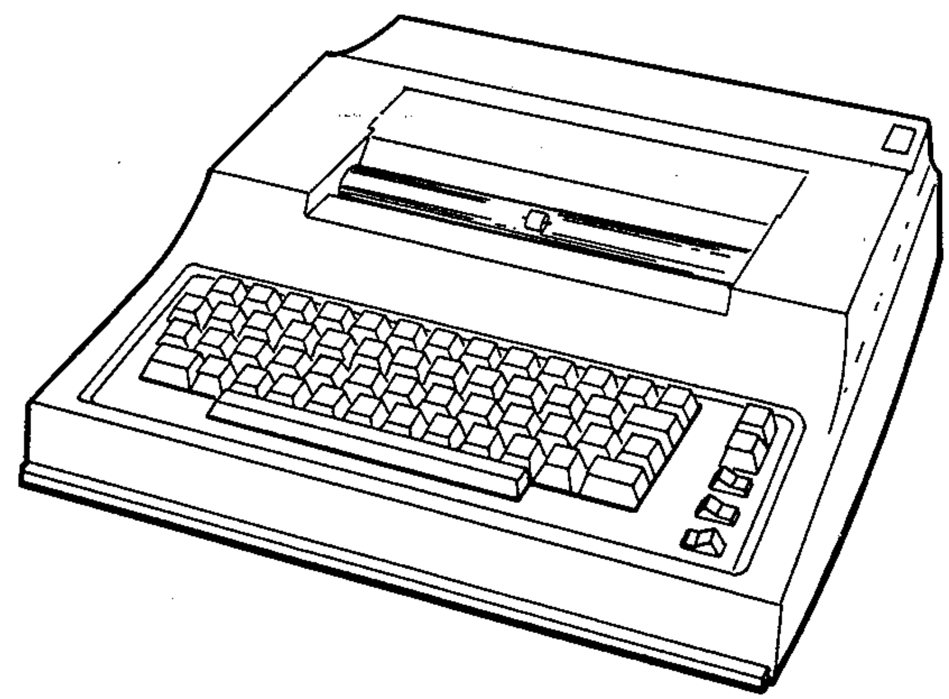


Figure 1-15. A Typical Hardcopy Terminal: TTY

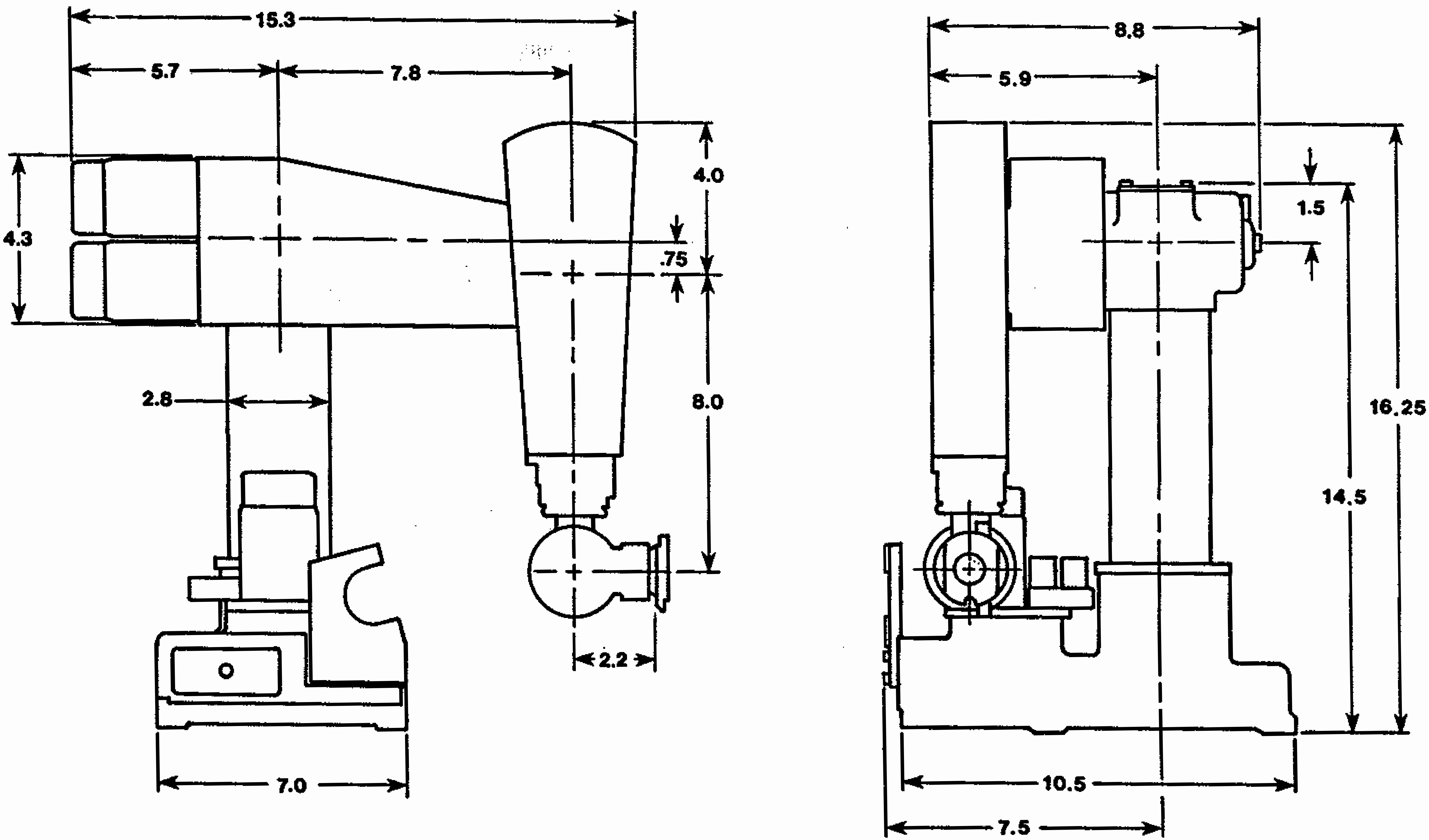
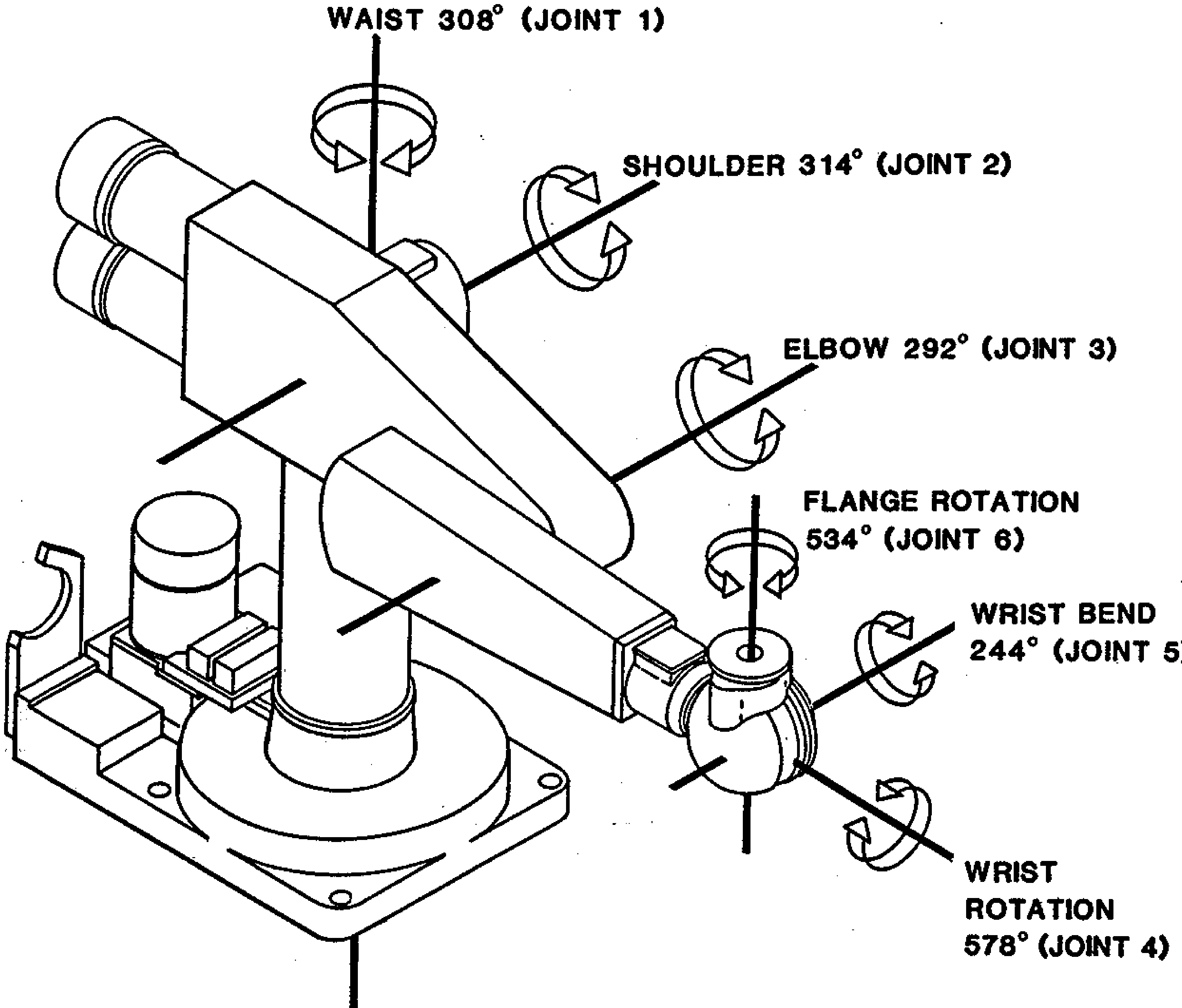
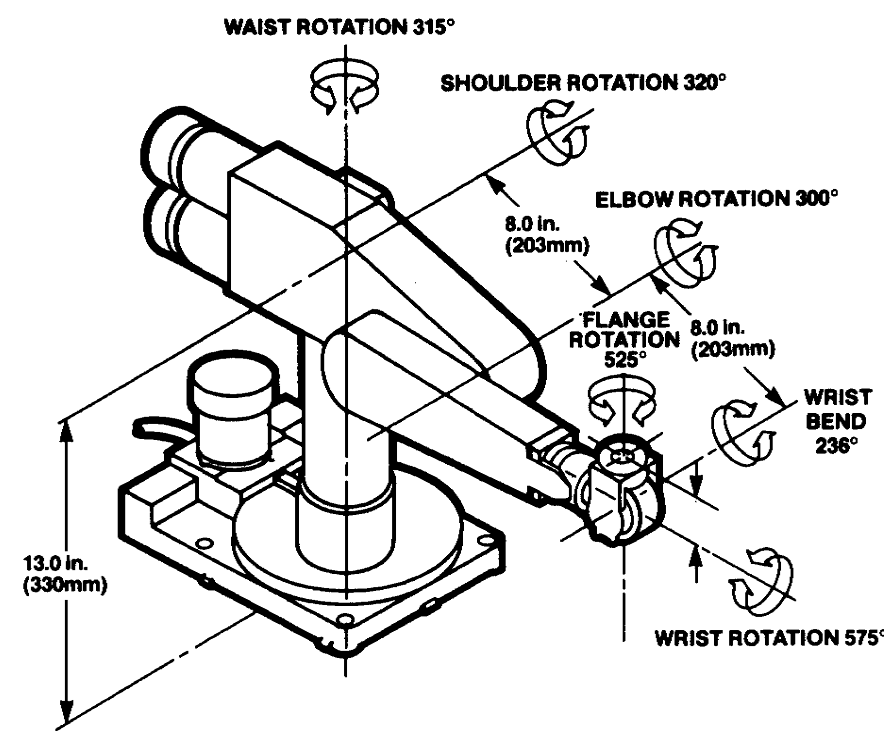


Figure 2-1. PUMA Dimensions - Installation


WAIST 308° (JOINT 1)
SHOULDER 314° (JOINT 2)
ELBOW 292° (JOINT 3)
FLANGE ROTATION 534° (JOINT 6)
WRIST BEND 244° (JOINT 5)
WRIST ROTATION 578° (JOINT 4)

UNIMATE PUMA
200 Series



Performance

REPEATABILITY	±.002 in. (±0.05 mm)
LOAD CAPACITY	2.2 lbs. (1.0 Kg)
STRAIGHT LINE VELOCITY	49.0 in/s max. (1.25 m/s max.)
ENVIRONMENTAL	50-120°F (10-50°C)
REQUIREMENTS	80% humidity (non-condensing). Shielded against industrial line fluctuations and human electro-static discharge

Physical Characteristics

ARM WEIGHT	15 lbs. (6.8 Kg)
CONTROLLER SIZE	19" x 12.5" x 23.6" (475 mm x 312.5 mm x 590 mm)
CONTROLLER WEIGHT	80 lbs. (36 Kg)
CONTROLLER CABLE LENGTH	15 ft. (4.5 m) Standard 50 ft. (15 m) Optional

General Specification

CONFIGURATION	6 revolute axes
DRIVE	Electric DC servo
CONTROLLER	System Computer (LSI-11/2 or 11/23)
Teaching Method	By manual control and/or computer terminal
Program Language	VAL or VAL II
Program Capacity	16K CMOS user memory std. (32K for VAL II)
External Program Storage	Floppy-disk (optional)
GRIPPER CONTROL	4-way pneumatic solenoid
POWER REQUIREMENT	110-130 V AC 50-60 Hz, 500 W
OPTIONAL ACCESSORIES	CRT or TTY terminals, floppy-disk memory storage, I/O module, 8 input/8 output signals (max. 32)—isolated AC/DC levels. Pneumatic gripper w/o fingers

What does the Puma’s workspace look like?

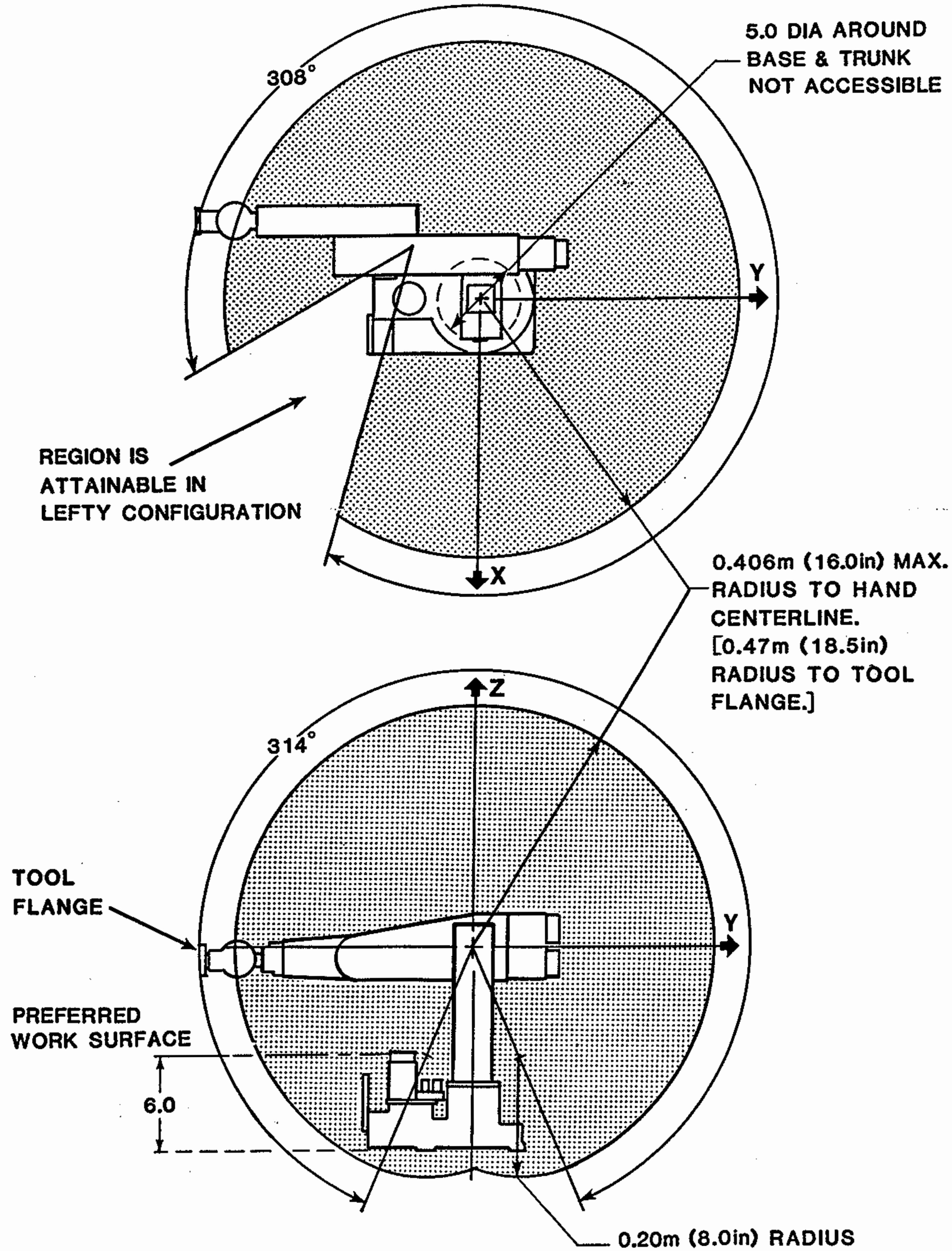
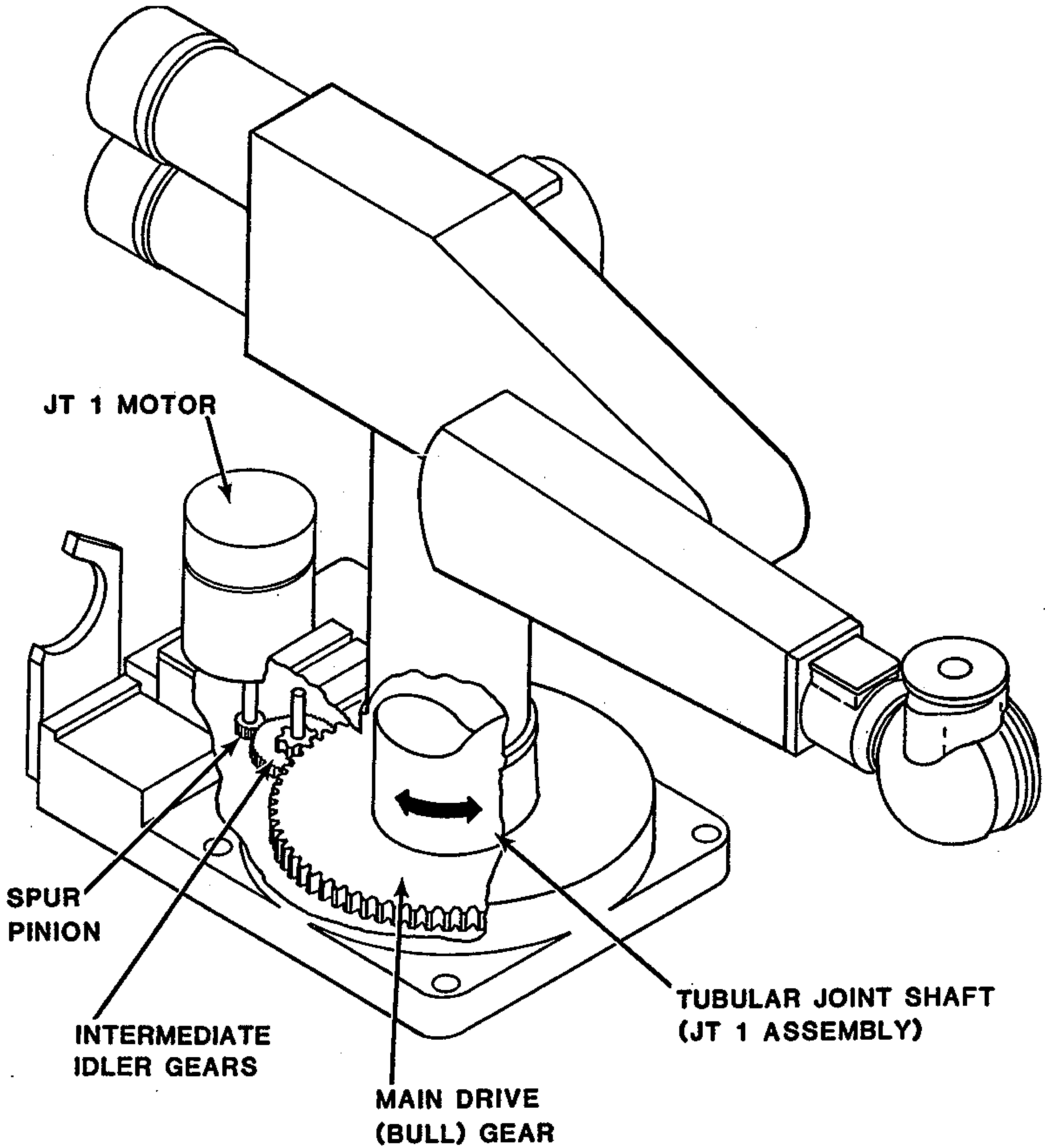
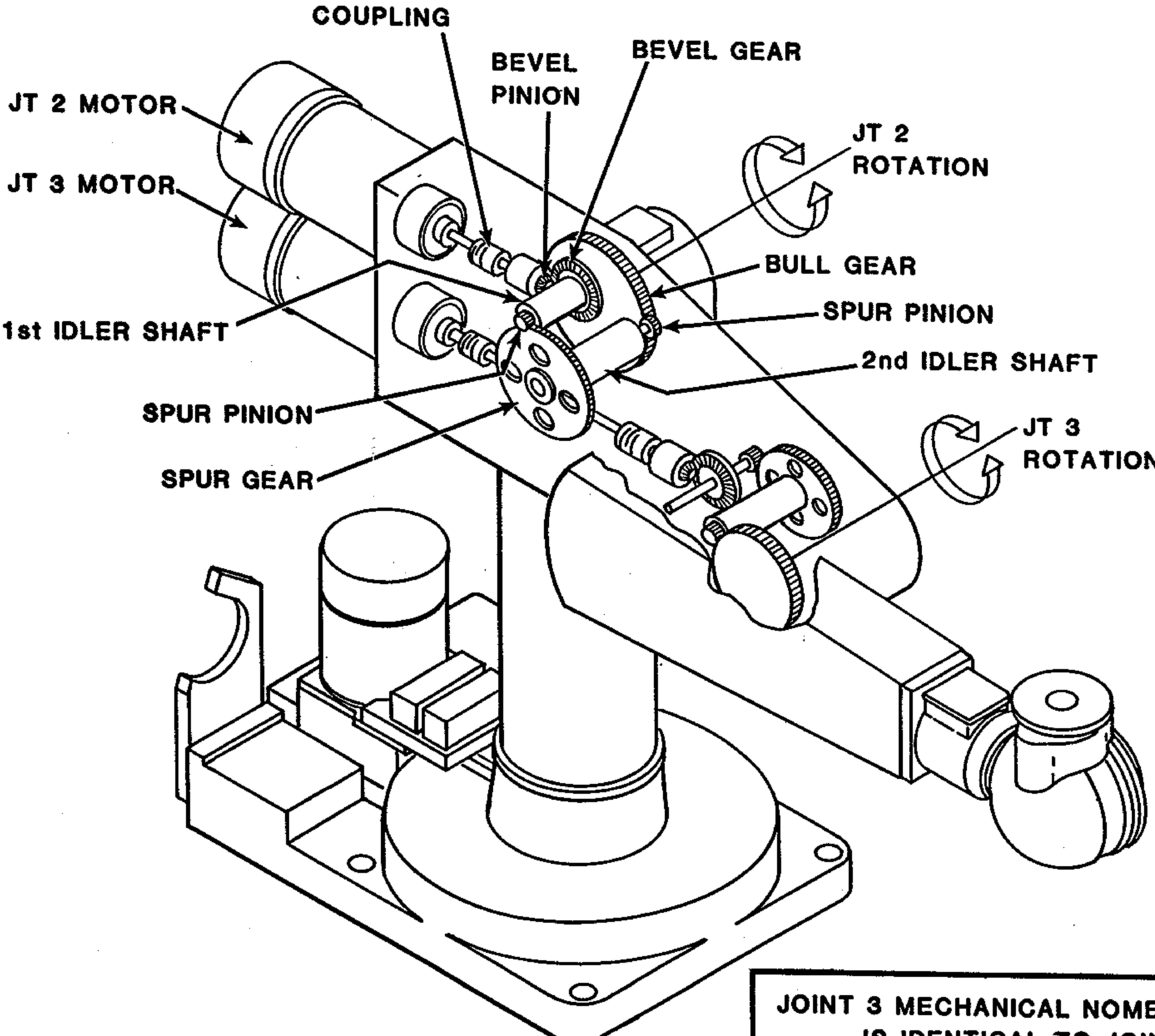


Figure 2-2. Robot Arm: Operating Envelope

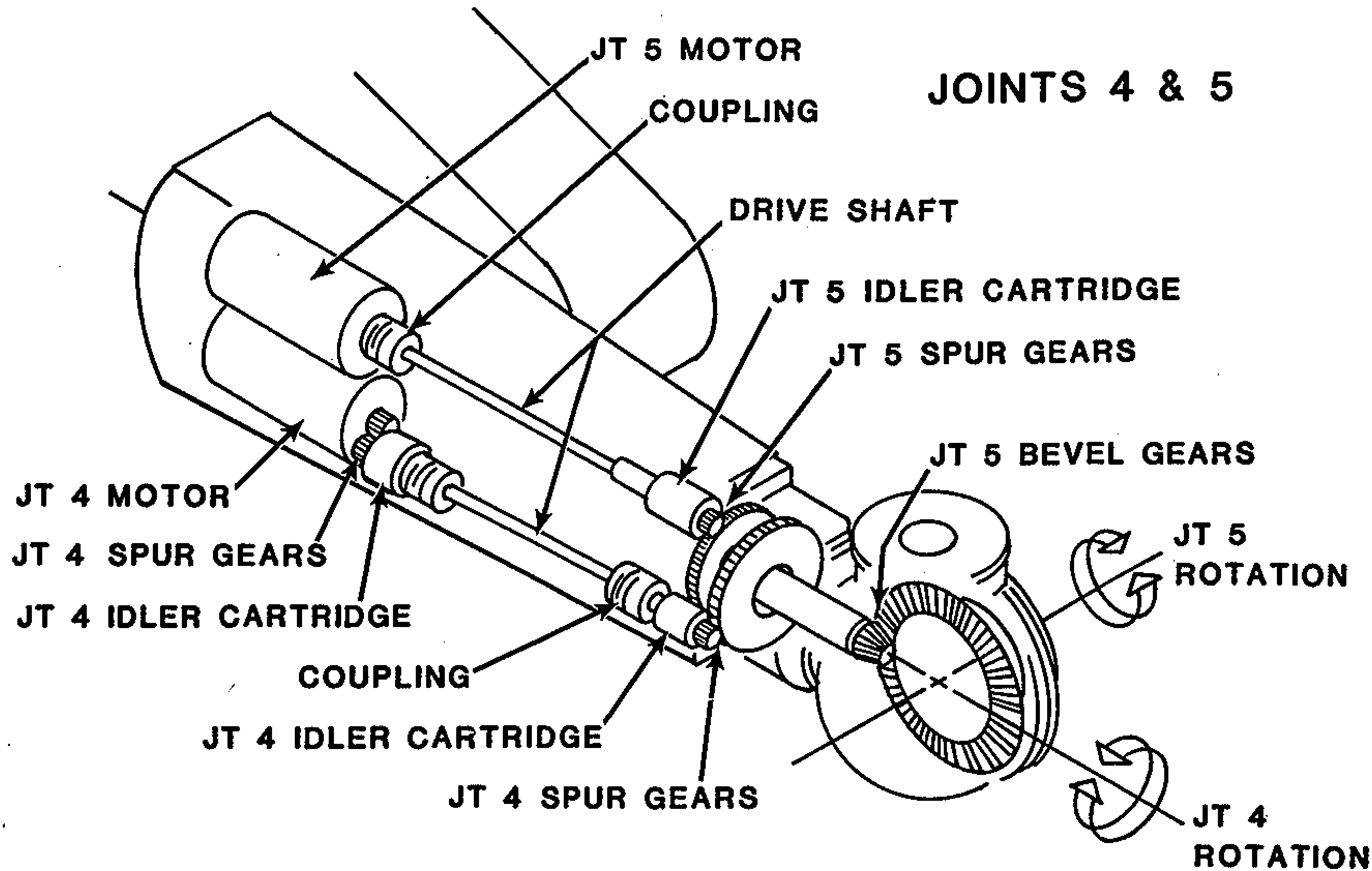
How does the Puma work?


JT 1 MOTOR
SPUR PINION
INTERMEDIATE IDLER GEARS
MAIN DRIVE (BULL) GEAR
TUBULAR JOINT SHAFT (JT 1 ASSEMBLY)

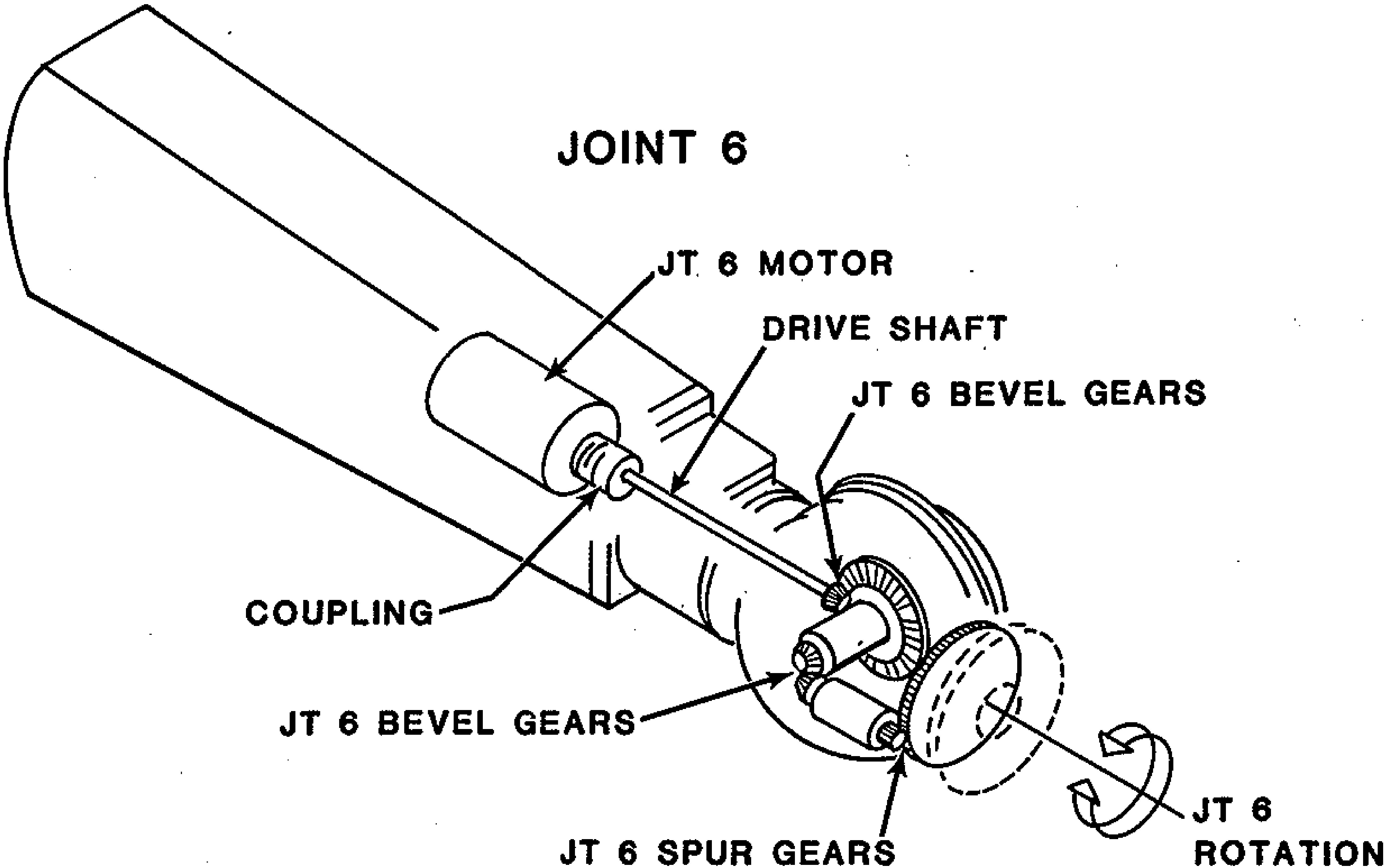


JOINT 3 MECHANICAL NOMENCLATURE IS IDENTICAL TO JOINT 2

JOINTS 4 & 5


JT 5 MOTOR
COUPLING
DRIVE SHAFT
JT 5 IDLER CARTRIDGE
JT 5 SPUR GEARS
JT 5 BEVEL GEARS
JT 5
ROTATION
JT 4 MOTOR
JT 4 SPUR GEARS
JT 4 IDLER CARTRIDGE
COUPLING
JT 4 IDLER CARTRIDGE
JT 4 SPUR GEARS
JT 4
ROTATION

JOINT 6


JT 6 MOTOR
DRIVE SHAFT
JT 6 BEVEL GEARS
COUPLING
JT 6 BEVEL GEARS
JT 6 SPUR GEARS
JT 6
ROTATION

First Step in Project 1

Derive full inverse kinematics for the Puma 260

Given desired x, y, z position of LED and Euler angles for the end-effector, plus the current joint angles of the robot, calculate all the joint angles needed to reach the new desired configuration

Full assignment and MATLAB starter code will be distributed around Tuesday of next week

You will do this in teams of three

Team Formation

You will work in a team of 3
(33 teams of 3, only one team of 4)

Each team must have at least one undergraduate
and at least one graduate student.
Submatriculants count as undergraduates.
(52 undergrads, 51 grads)

Try to have two MEAM students and one non-MEAM
student on each team
(71 MEAM, 33 non-MEAM)

Pick your team by 5pm on Thursday, October 11
(one week from today)

Speed Meeting Activity

Stand up, and leave your stuff where it is.

All undergraduates stand around the edges of the room.

Grad students - go stand in front of an undergraduate.

Introduce yourselves: name, major, favorite robot.

Rotate!   Rotate!   Rotate!   Rotate!