**ME192 Midterm Exam 2**

**October 29, 2014**

Name \_\_\_\_\_\_\_\_Key \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Score \_\_\_\_\_100\_\_\_\_\_

12

1. In what sequence are computed in the Pieper’s method? 🡪

Of the two special cases in the “r & z” equations below, which case is easier to solve and why?

The “z” equation is easier to solve because for the “r” equation introduces quadratic terms (*which will turn out to be 4th order polynomial equations, a messy undertaking*.)

5

  where,

,  , ,, and

In the case of six axis robots, the Z-Y-Z Euler angles may be used for solving the joint angles between wrist and gripper. What must be known to be able to use the angle set solution? The rotation matrix at the end effecter. Is it reasonable to assume that it is known? Elaborate.

3

Yes. The whole inverse kinematics solutions presented in the book are based on given which is reasonable because when the gripper location is defined, the can easily be extracted from the robot controller. When is extracted, and are calculated, then can be determined.

4

No. The issue here is when is set, so are and therefore there is no inverse kinematics problem. In other words, cannot be given without setting  which is a forward kinematics.

In practice, a six axis robot controller will store a large number of the location transformations in the work space and when an exact position is specified, the angle set solution can quickly be found through a combination of position interpolation and forward kinematics calculations without having to carry out inverse kinematics calculations.

1. The Pieper’s solution requires solving a series of quadratic equations substituting the transcendental equations. State the most likely reason for the faults other than round-off errors that are often seen in solving the quadratic solutions.

6

3

1. Division by zero in the denominator:

The variable substitutions, or a conversion “from θ to u” for quadratic solution, is not applicable in the case.

1. The quantity inside the radical in the quadratic solution is negative:

3

There is no solution. In other words, the position specified is unreachable.

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1. In a 6-axis robot operation, an object is to be picked up with a fixed gripper angle and approach.

How many remaining joint angles require a non-trivial calculations? Three (finding θ1 is trivial)

2.5 ea

How many angle set solutions should normally be available? Infinite number

If a five axis robot is used, how many angle set solutions are there? Two

When will a workspace-interior singularity occur on remaining angles? The links stretch out to end.

2

How many solutions are possible at a singularity point? The answer is in the question.

1. An object is captured by a camera mounted on the Z axis of a SCARA robot. Given the below notations for transformation, find the “XYZR” pick up position in the robot (base) frame based on the “xyr” object position in the camera frame. The transformation vectors of the Z-axis and the camera frame are stripped of the Z and rotation angle values. Assume that the inversions are readily available.

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(BTZ) Variable XY position of the Z-axis as the vision reference point – in the robot frame.

(ZTC) Calibrated XY offset of the camera (0, 0) position, calibrated - in the Z-axis frame

(CTO) Variable xyr position of the object - in the camera frame

(ZTG) Calibrated or taught-once XYZR position offset of the gripper - in the Z-axis frame.

Find the XY pickup location in the robot frame with the gripper at the center of the Z axis.

OBJ.LOC = [ BTZ:ZTC:CTO ] or

3 ea



Find the XYZR pickup location in the robot frame with the gripper offset from the Z axis.

PICK.LOC = [ OBJ.LOC : GTZ ] or

3 ea



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1. Complete a V+ code for extracting by moving the gripper to a known object position BTO.

*Method 1* – Decompose obtained by moving the gripper to the sample position

HERE BTG

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DECOMPOSE V[1] = BTO

SET ZTG = BTG : TRANS(-V[1], -V[2], -V[3], , , -V[6])

*Method 2* – Induce ZTG to take on a position relative to BTZ at the sample location.

4

HERE BTZ:ZTG.

*Once ZTG is found, set the future pickup position equal to BTO offset by ZTG.*

*SET PICK.LOC=BTO:ZTG*

5

1. In Lab 3 a square object is found by testing the existence of lines at the maximum edge distance divided by. What simple method should be employed to test for a general rectangular shape instead of a square? *Note: The lab used VFEATURE( ), VRULERI, VFIND.LINE for square test.*

*Collect the minimum edge distance as well as the maximum edge distance. If the minimum value is significantly less or greater than* (or 70%) *of the maximum value, the object is a rectangle.*

1. Given a RRR robot with the kinematics shown in Fig. 2 and

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1. Fill in the second and the third rotation matrices for Joint 2. The second matrix represents a 90° “between-frame” rotation about X.



3 ea

1. Find - when [θ1, θ2, θ3] = [0°, 30°, 60°], and [*l*1, *l*2, *l*3] = [0, 2, 1]

   

2 ea

1. Complete the derivation of a 3x3 Jacobian matrix from above for velocity transformation.



1.5 ea

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1. In Fig. 1 below, a position vector *BP* is stationary in frame {B}, but the frame is rotating about an instantaneous axis K at the magnitude ω and in the direction implied in ΩB.

6

Find r = \_P(t)sinθ\_\_\_\_\_ α = \_\_ωΔt\_\_\_\_\_\_\_\_\_ ΔP = \_\_\_ P(t)sinθ ωΔt\_\_\_\_\_\_\_\_\_\_\_\_\_

Seen from {A}, the velocity of *BP* due to its frame {B} rotating at velocity ΩB, is given by

4



In the equivalent axis of rotation involving axis  and the velocity of angle θ, Ω

can be expressed as

ω

3

K

r

α

ω

ΔP

P(t+Δt)

P(t)

θ

Figure 1. Positions vector velocity due to rotating axis

State the significance of skew symmetricity in cross-multiplied vectors as in  in light of the convenience of vector or matrix representation and the computational efficiency.

We can convert a vector representing an angle-axis rotation into a matrix form or vice versa as needed in setting up matrix transformation equations.

4

9

1. Convert the velocity transformation in terms of frame {A},, to frame {B},, by multiplying out the RHS of the matrix equation and rearranging the terms back to a matrix form.

``

3 ea





**Figure 2. R-R-R Robot Kinematics**

Z

Z

X

Y

X

Y

**θ**

**1**

**θ**

**2**

**θ**

**3**

**L**

**3**

**L**

**2**

**L1**

**0**

(x,y,z)

**z**

**r**

**x**

**y**

(

x

,

y, 0)

**R**

**R**

**R**

1. Extra Credit Take-Home Problem – PLC implementation of Single button ON/OFF Switch

Individual work. No collaboration. (Due 11/1/14)

With no or minimal use of delay timers, counters, Rising Edge/Falling Edge switches, or SET/RESET relays, develop a one-button push-On, push-Off ladder logic program. The PLC software and its simulator may be downloaded from the link below.

*http://support.automationdirect.com/products/domore.html*

*Points assigned*

12.5 No timers, counters, RE/FE switches, or SET/RESET outputs are used.

10 Only provision is used.

7.5 Two provisions are used.

5 A “freak” PLC circuit that works, but cannot logically be explained.

0 The program is not tested or non-functional.

15 A break through with a rung count of three or less and with a switch debouncing.

Notes:

*There is no limit to the number of rungs in the program.*

*The output may be turned on/off at the rising or falling edge of the switch or with a delay.*

*A single button ON/OFF switch normally requires a debouncing circuit to work reliabily.*