Department of Electrical Engineering

EEL704, Robotics & Automation,
Major Test , *2006-2007/II.*
Max. time : 2 hours, Max. marks: 80.

Marks: Q1: 10, Q2: 10, Q3: 12, Q4: 13, Q5: 10, Q6: 12, Q7: 13

- Write clearly each step of your calculation.

Q1 Suppose a perspective transformation of is given by $T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & -\frac{1}{\lambda} & 1 \end{bmatrix}$ with $\lambda = 1.0$.

Find the world coordinates whose image points are of the form $[x_0 \;\; y_0 \;\; 0]^T$. What is the expression of Z and explain reasons for any discrepancy in results?

Q2. (a) Suppose a transformation $T = T_B^A$ where $T = \begin{bmatrix} 0.866 & -0.5 & 0.0 & 10.0 \\ 0.5 & 0.866 & 0.0 & 0.0 \\ 0.0 & 0.0 & 1.0 & 5.0 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix}$

Draw the frame diagram which qualitatively shows their arrangement.

(b) Frames describing the base of a robot and an object are given relative to the universe

$$T_{obj}^{U} = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & -1 & 4 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, T_R^U = \begin{bmatrix} 0 & -1 & 0 & 2 \\ 1 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

Find a transformation of the Robot configuration T_{obj}^{R} if the hand of the robot is to be placed on the object.

(c) Explain briefly the physical significance of Jacobian in the context of serial link manipulator.

Q3. Suppose **R** is a rotation matrix and S(**a**) is the skew symmetric matrix corresponding to vector **a**. For any vector **a** and **b** belonging to $\Re^3$, show that

(a) $\mathbf{R}\, S(\mathbf{a})\, \mathbf{R}^T = S(\mathbf{Ra})$

(b) Suppose $\mathbf{a} = [1 \;\; -1 \;\; 2]^T$ and $\mathbf{R} = \mathbf{R}_{x,90}$. Compute $S(\mathbf{Ra})$.

(c) Figure 1 shows a mass spring system. Derive the equation of motion using Euler-Lagrange equation.

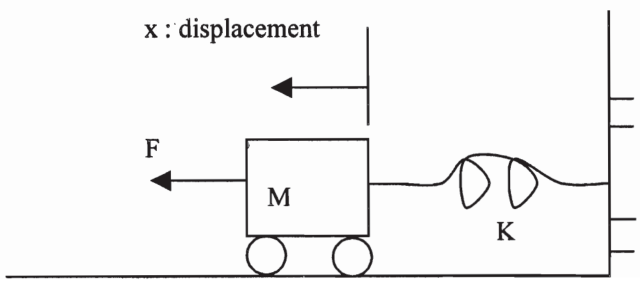

Figure 1

Q4. The dynamics of a single link manipulator is given by

$$5\ddot{\theta} - 8\sin\theta + 2\,\theta\dot{\theta} = u$$

(a) Suppose, a link is motionless at $\theta=0^0$ and it is desired to move the joint to $\theta=45^0$ in 3 secs with 0 velocity at final point. Find a cubic polynomial $\theta_d(t)$ to define the path?

(b) Design a trajectory following controller such that the system is always critically damped with closed loop stiffness $= 10$ to track $\theta_d(t)$ (defined in part (a)).

(c) Analyse the closed loop stability of the above system using Lyapunov stability theory.

Q5. Consider a n link manipulator described by

$$M(\theta)\ddot{\theta} + V(\theta,\dot{\theta})\dot{\theta} + G(\theta) = u$$

where $M(\theta)$ is the inertia matrix, $V(\theta, \theta)$ is the corriolis forces and $G(\theta)$ is gravity term. To track a constant trajectory θ_d, a control law is given as $u = K_pE - K_d\dot{\theta} + G(\theta)$ where K_p, K_d are positive definite diagonal matrices, error $E = (\theta_d - \theta)$. Show that the closed loop system is asymptotically stable using a suitable Lyapunov function.

Q6.(a) Explain briefly the different components of a fuzzy logic based inferencing system.

(b) Explain two methods for computing the intersection two fuzzy sets.

(c) Consider a fuzzy set A = 0.1/1 + 0.5/2 + 0.8/4 + 1/5 + .8/6 + 0.2/-2 + 0.1/-1.

Suppose a function $f(x) = x^2$. Find the fuzzy set f(A)?

Q7. Figure 2 shows an image where 0 & 2 corresponds to background and object image respectively. each pixel of figure 2 is of unit length and the origin is assumed to be the top left-hand corner of the image.

(a) Using sobel operators, find the gradient at pixel denoted as p.

(b) Which type(s) of connectivity exist between the pixels p and q. Justify your answers.

(c) Express the zero moment in terms of pixels?

(d) What is the position and orientation of the connected component.

Origin **Y**

0	0	0	0	0	0	0	0
0	**2**	**2 q**	0	0	0	0	0
0	**2**	**2**	**2 p**	0	0	0	0
0	**2**	**2**	**2**	0	0	0	0
0	**2**	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Figure 2

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