ACA & Department

Sample Questions for

Qualifying Examination

in

2000 - 2001

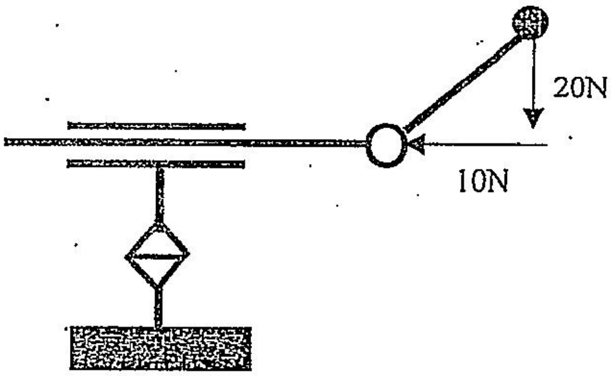
(held in May 2001)

liu

Sample

As shown below, forces 10N and 20N are acting on the 3 DOF arm. The moment of inertia of the first link about the joint axis is $I_1=0.25kgm^2$. The second link is a massless bar. The mass of the third link is 1kg and concentrated at the endpoint. The first and third links are both 1m long. Denote the inputs of the joint actuators by $u=(u_1,u_2\ u_3)^T$.

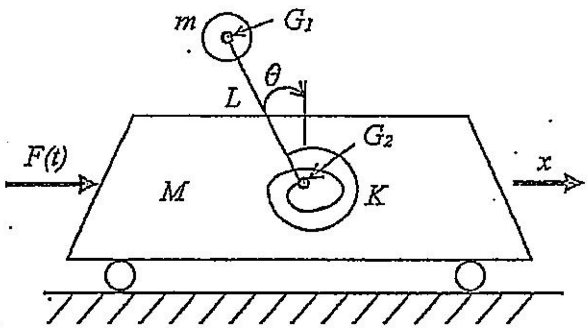
1) Derive the dynamic equation of the manipulator;
2) Describe properties of the dynamics; and
3) Design controllers for its position control and trajectory tracking.



Liao

Sample Problem:

The system shown below consists of an inverted pendulum standing on a translating platform. The pendulum head is a uniform rigid disk with mass m, and is pinned to a massless rod at G_1. G_1 is the mass center of the circular disk. The other end of the rod is attached with a torsional spring (spring constant K) and pinned to the mass center of the platform G_2. Derive the equations of motion.

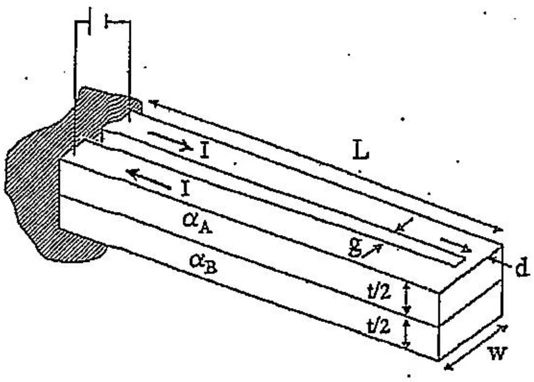


Wen

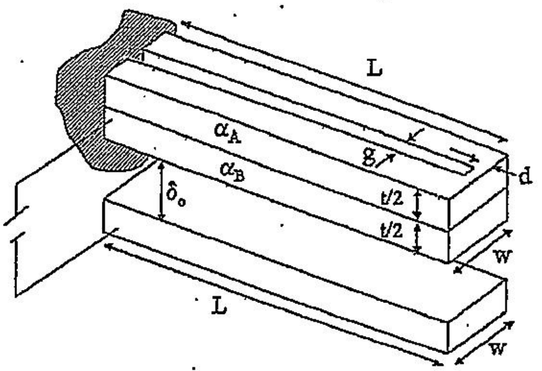
Qualifying Examinatin – MEMS (Wen J. LI)

(Sample Question)

Consider a thermal bimorph actuator and an electrostatic actuator as shown below. If we would like to deflect the actuators by a distance δ_0, which is the gap distance between the electrodes of the electrostatic actuator, compare the power required to do this for each type of the actuators by finding the ratio of P_t and P_e, where P_t is the power required for the thermal actuator and P_e is the power required for the electrostatic actuator. You may do the comparison for the steady-state case, i.e., neglect the time delay required to reach equilibrium for the thermal actuator. You may also assume that the electrostatic actuator will draw a current I when a voltage V is applied; also, the power required for the thermal actuator is proportional to the temperature change ΔT, i.e., $P_t = \beta\,\Delta T$, where β is a constant. Please write down any assumptions you have used to do the comparison.



Thermal Actuation



Electrostatic Actuation

Jre

Jre

Qualifying Examination, May 2001

1. Sample

Consider the system

$$\begin{aligned} \dot{x}(t) &= Ax(t) + Bz(t), \quad x \in R^n, z \in R^1 \\ \dot{z}(t) &= f(x(t), z(t)) + u(t), \quad u \in R^1 \end{aligned} \qquad (1)$$

where $A \in R^{n\times n}$, and $B \in R^{n\times 1}$ are constant matrices, $f(x,z)$ is a smooth scalar function for all $x \in R^n$, $z \in R^1$, and $f(0,0) = 0$. Assume there exist a row vector $K \in R^{1\times n}$, and a symmetric positive definite matrix $P \in R^{n\times n}$ such that

$$(A - BK)^T P + P(A - BK) = -I_{n\times n}$$

(a) Find a state feedback control of the form $u = \phi(x, z)$ such that the origin of the closed-loop system

$$\dot{x}(t) = Ax(t) + Bz(t), \quad \dot{z}(t) = f(x(t), z(t)) + \phi(x(t), z(t)) \qquad (2)$$

is globally asymptotically stable.

(b) Find a Lyapunov function for system (2) which is radially unbounded and whose derivative along all the trajectories of (2) is globally negative definite.

Yam.

Sample Problem

1. Consider the scalar system

$$\dot{x} = \alpha x + u$$

where α is a constant. The performance index is

$$J = x(T) - \frac{1}{2}\int_0^T u(t)^2 dt$$

The initial condition is $x(0) = 0$.

(a) Write down the Hamiltonian function, the state and co-state equations, and the stationarity condition.

(b) Write down the boundary conditions.

(c) Determine the Lagrange multiplier $\lambda(t)$.

(d) Obtain the optimal solutions $u^*(t)$, $x^*(t)$, and show that

$$J^* = \frac{1}{2\alpha} e^{\alpha T} Sinh(\alpha T).$$

Sample Question for MAE5090 Topics in Robotics :

What are holonomic and non-holonomic constraints of robot motion?

A two-wheeled service robot is to navigate in an indoor office environment whose information is not available beforehand. Assume that the robot has ultrasonic sensors, a camera and the encoders for measuring the turning angles of the wheels. Develop methods for the robot to construct the map of the working environment, to localize itself and to successfully move from offices to offices in the environment.

Jun

In simulated annealing, compare the two typical updating probabilities:

$$P(\Delta E) = \begin{cases} 1 & \text{if } \Delta E < 0 \\ \exp(-\Delta E/T) & \text{otherwise} \end{cases};$$

$$P(\Delta E) = \frac{1}{1 + \exp(\Delta E/T)}.$$

For a given T which one has a higher chance for E to increase? Why?

Question 6 (by Prof. Jun Wang)

A recurrent neural network is described by the following state equation and learning equation:

1) State equation:

$$\frac{du_i}{dt} = -u_i + \sum_j w_{ij}v_j + x_i, \; v_i = f(u_i)$$

where $w_{ij} = w_{ji}$, $f(u_i)$ is a bipolar sigmoid activation function.

2) Learning equation:

$$\frac{ds_{ij}}{dt} = v_i v_j, \; w_{ij} = Mf(s_{ij}),$$

where $0 < M < +\infty$.

Use a Lyapunov function $E(v, w) = -\frac{1}{2}\sum_i \sum_j w_{ij}v_i v_j - \sum_i x_i v_i + \sum_i \int_0^u f^{-1}(\nu)d\nu$, prove the stability of the recurrent neural network.

Question 6 (by Prof. Jun Wang)

Consider a discrete-time Hopfield network, as an associative memory, described by the following dynamic equation:

$$u(t+1) = Wv(t), v(t) = \text{sgn}(u(t)), u \in R^4, v \in \{-1, 1\}^4.$$

where W is encoded for storing the following 2 patterns $s^1 = (1, -1, -1, 1)^T$ and $s^2 = (-1, 1, -1, 1)^T$. Show the resulting connection weight matrix, energy function, and all equilibria (including the spurious ones which are not the stored patterns) with minimum energy level. What is the minimum energy level?

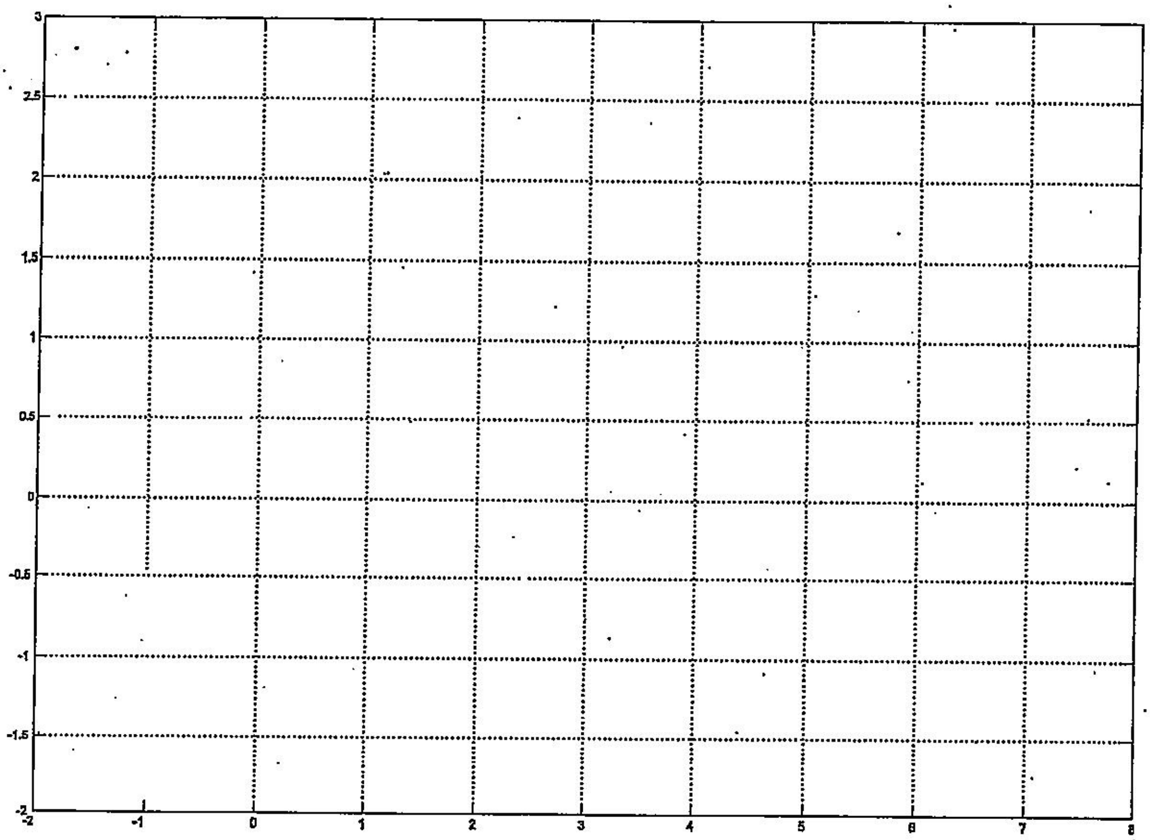
MW.

A quadratic Bezier curve has the following control points:

$$P_0 = (1,-1); P_1 = (7,1); P_2 = (4,3)$$

(1) We can take the first half of the curve, i.e., $0 \le t \le 0.5$, and re-parameterize this curve so that the parametric range becomes $0 \le t \le 1$. This is known as subdivision. Find the new control points of the re-parameterized curve, and show them on the graph below (mark them Q)

(2) For the re-parameterized curve in (1), we want to subdivide it one more time. Find the new control points of the first half of this re-parameterized curve, and show them on the graph below (mark them W).



Ronald

1. (a) Name the two basic assumptions used for optical flow computation. Are the assumptions realistic? What would happen to the optical flow estimation if they are violated?

   (b) An object being pictured by a camera moves relative to the camera. Briefly describe the essential characteristics of the optical flow in each of the following motions of the object:

      i. Translation at constant distance to the camera;
      ii. Translation in depth relative to the camera;
      iii. Rotation at constant distance about the view axis of the camera;
      iv. Rotation of a planar object perpendicular to the view axis of the camera.

— END —

Du

Sample Question for QE/CE MAE 5100, Winter 2009

1. A soap packing line encounters the problem of missing soaps in its paper box. Since the box is not transparent, it is not possible to use visual inspection to detect which box contains no soap. Design a system that can solve this problem.

2. Everyday, hundreds of electronics systems are discarded in Hong Kong. Design a system that can create a win-win situation for the consumer and your recycling business.

3. The link, http://en.wikipedia.org/wiki/Crank_(mechanism), shows a crank mechanism. Derive its kinematical model and analyze its behavior. You can assume the missing dimensions.

4. The link, http://en.wikipedia.org/wiki/Maltese_Cross_mechanism, shows a so-called Geneva mechanism. Derive its kinematical model and analyze its behavior. You can assume the missing dimensions.

5. High-Performance Liquid Chromatography Optimization. In many pharmaceutical applications of high-performance liquid chromatography (HPLC), it is of outmost importance to find optimal separation conditions for different products. This exercise is based on a study performed in a pharmaceutical industry laboratory.

   Problem: to find an optimal analytical method for a pharmaceutical product.
   Control variables: three control (experimental) variables were used. The settings ar specified in the table below.

	Ref. value	Step size
pH	5	0.5
ACN, %	16	1
Temperature, °C	45	5

   Response variables: three different response variables were used to characterize the outcome. The settings are specified in the table below.

	Objective	Low limit	High limit	Importance
Resolution 12	Maximization	0	10	High
Resolution 23	Maximization	0	10	High
Resolution 34	Maximization	0	10	High

   The shape of the membership functions was proportional for all three responses.

Experiment results: the results from the 11 optimization trials are shown in the table below.

pH	ACN, %	Temp., °C	Rs 12	Rs 23	Rs 34
4.75	16.5	42.5	0.5583	1.343	1.884
4.75	15.5	47.5	0.8970	1.508	2.007
5.25	15.5	42.5	0.7992	2.132	0
5.25	16.5	47.5	0.5351	1.420	0
4.58	15.2	40.8	0.6888	2.937	1.879
4.25	14.5	37.5	0.6492	0	0
4.14	15.9	44.7	0.5692	0	0
4.97	15.6	43.1	0.7596	1.179	2.299
4.79	14.4	45.1	1.108	1.300	2.657
4.44	14.4	45.9	1.009	3.408	2.048
4.18	13.8	47.3	1.270	4.530	2.017

Exercises: analyze the experiment results and find the optimal solutions.

Human walking can be modeled by an invert pendulum model as depicted below. (a) Derive the mathematical model; (b) Assuming that the knee bending is considered, find the ankle and knee angles; (c) Based on the model above, discuss when the personal is most likely to fall.

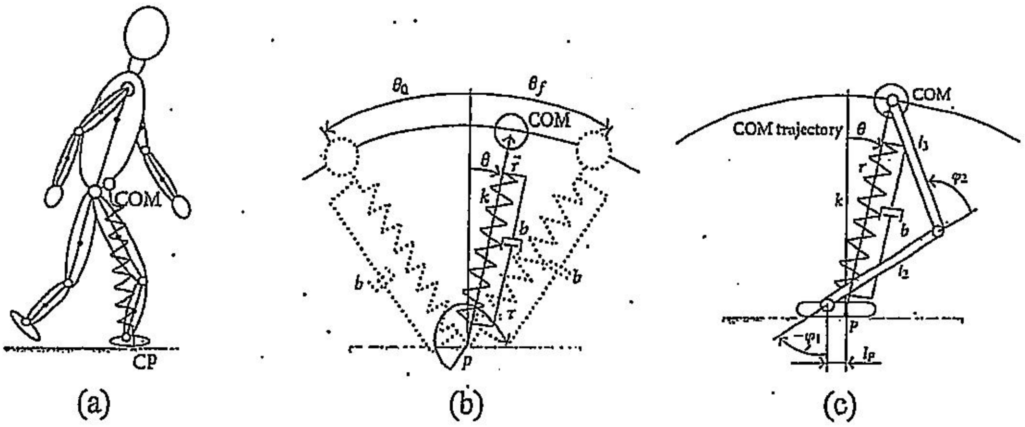


Figure: Illustration of the human waling model

Question for MAEG 5030

Consider a Bezier patch $S(u,v)$ with 4 x 4 control points $P_{i,j}$, a bilinear surface patch $B(a,b)$ with four corner points (u_1,v_1), (u_2,v_2), (u_3,v_3), (u_4,v_4) in the u,v-domain (where $0 \le a,b \le 1$), the composition of two surface patches is in a form of $F(a,b)=S(B(a,b))$. Such a composition actually implements a function of surface trimming by a four-sided region (i.e., (u_1,v_1), (u_2,v_2), (u_3,v_3), (u_4,v_4)). It can be proved that the resultant patch $F(a,b)$ is also in the form of a Bezier patch (but with higher order). What are the control points of the patch $F(a,b)$?