2023 Master's Program, Graduate School of Design (General Entrance Examination) Achievement Test Question Sheets

Examination Subject
Media Engineering

[Compulsory Question] Answer the following question.

1. Select six of the following 22 technical terms, and explain each. [60 points, 10 points each]

(1) Autoencoder
(2) Brain in a Vat
(3) Crossmodal
(4) Development of 3D body
(5) Dimensional analysis
(6) Edge preserving smoothing
(7) Error diffusion
(8) Flow visualization
(9) Fourier transform
(10) Global illumination calculation
(11) Histogram matching
(12) Hough transform
(13) Median filter
(14) Meta Ball
(15) Natural Image Resizing
(16) Photometric stereo
(17) Photon mapping
(18) Precision and recall
(19) Radiosity algorithm
(20) Ray tracing
(21) Thermal effusivity
(22) World Wide Web

[Elective Questions] Choose and answer two questions from the following question 1 through 6.

Question 1 [70 points]

[1] A digital image f_{ij} (i= 0, 1,$\cdots$, N; j= 0, 1,$\cdots$, N) is processed using Equation (1) to obtain a resultant image g_{ij}, where h_{kl} (k=$-m$,$\cdots$,-1,0,1, $\cdots$, m; l=$-n$,$\cdots$, -1, 0 , 1, $\cdots$, n) is a two-dimensional array.

$$g_{ij} = \sum_{k=-m}^{m} \sum_{l=-n}^{n} h_{kl} f_{i+k,j+l} \qquad (1)$$

Answer the following questions. [30 points]

(1) What is the operation expressed in Equation (1) generally called? (5 points)

(2) What is the name of h_{kl} in Equation (1)? (5 points)

(3) Explain how this equation can be used to process any image. (20 points)

[2] In order to process an analog image on a computer, it is necessary to digitize the image. Explain how this is done. [20 points]

[3] In the two-dimensional plane representing an image, let (x, y) be the coordinate system before transformation and (u, v) be the coordinate system after transformation. What is the transformation represented by equation (2) called? In addition, explain what kind of transformation can be performed on the image by this formula. [20 points]

$$\begin{pmatrix} u \\ v \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} e \\ f \end{pmatrix} \qquad (2)$$

Question 2 [70 points]

[1] Two consecutive frame images (left: one previous frame, right: current frame) are shown in the figure below, where the 2 x 2 pixel region enclosed by the rectangle shows the moving object. Estimate the moving direction of the object by performing motion compensated prediction coding, assuming that the object can move only to horizontally, vertically or diagonally adjacent pixels. [35 points]

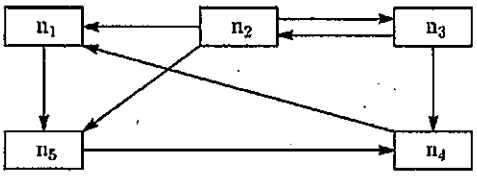
120	120	120	120	120	120
120	120	120	120	120	120
120	120	125	135	120	120
120	120	125	130	120	120
120	120	120	120	120	120
120	120	120	120	120	120
120	120	120	120	120	120
120	120	120	120	120	120

120	120	120	120	120	120
120	120	120	122	130	120
120	120	125	125	130	120
120	120	125	130	120	120
120	120	120	120	120	120
120	120	120	120	120	120
120	120	120	120	120	120
120	120	120	120	120	120

[2] When a camera and a single point light source have the same position which we consider at infinity from the object, draw the reflectance map. [35 points]

Question 3 [70 points]

[1] In the following figure, rectangles n_1 to n_5 represent web pages, and the arrows between rectangles represent links between web pages. Answer the following questions for the web page structure in the figure. [40 points]



(1) Show the adjacency matrix L and transition probability matrix **E** for the link structure shown in the diagram above. (10 points)

(2) Consider the transition of web pages based on the random surfer model without considering the damping factor. Using the transition probability matrix **E** obtained above, find a vector $v_2 = (p_1^2, p_2^2, p_3^2, p_4^2, p_5^2)^T$ representing the probability that a user viewing n_1 at time 0 will view each web page at time 2 (two steps later). Assume that p_i^t represents the probability of viewing Web page n_i at time t. Note that the elements of vector v_2 may be fractions. (10 points)

(3) Explain the differences in the concepts of PageRank and HITS, two typical ranking methods for web pages. (10 points)

(4) Explain how to collect the necessary web pages from the Internet to build a search engine. (10 points)

[2] Suppose that the ratings of users 1-3 for items 1-3 and the similarity between users are expressed in the following tables. Note that "?" denotes unrated. Answer the following questions regarding the recommendation system using the following ratings. [30 points]

	Item 1	Item 2	Item 3
User 1	2	5	?
User 2	4	2	1
User 3	5	1	2

	User 1	User 2	User 3
User 1	1.0	0.7	0.5
User 2	0.7	1.0	0.9
User 3	0.5	0.9	1.0

(1) As a simple user-based collaborative filtering method, suppose that the evaluation value $pred(a,x)$ of an unknown item x for user a is estimated by the following equation.

$$pred(a,x) = \frac{\sum_{i \neq a}(v_{i,x} \times sim_{a,i})}{\sum_{i \neq a}(sim_{a,i})}$$

Here, $v_{i,j}$ represents user i's evaluation of item j. On the other hand, $sim_{i,j}$ represents the similarity between user i and user j. This equation represents the estimation of user a's rating of unknown item x as a weighted average of other user i's rating of item x. The similarity between the users is used as weights. Furthermore, assume that the vector of evaluation values for user i is expressed as $v_i = (v_{i,1}, \cdots, v_{i,N})$, where N is the number of items, and the similarity $sim_{i,k}$ represents the similarity between user i and user k.
In this case, estimate the evaluation value of item 1 for user 3 using the above user-based collaborative filtering method. Note that the process as well as the calculation results should be shown. (10 points)

(2) Perform item-based collaborative filtering in a manner similar to the user-based collaborative filtering method shown above, and estimate the evaluation value of item 1 for user 3. Use the following table for the similarity between items. The process as well as the results of the calculation should be shown. (10 points)

	Item 1	Item 2	Item 3
Item 1	1	0.6	0.9
Item 2	0.6	1	0.8
Item 3	0.9	0.8	1

(3) Explain the advantages and disadvantages of collaborative filtering. (10 points)

Question 4 [70 points]

[1] Read the following sentences and answer the questions 1 to 4. [35 points]

In physics-based animation, collision detection between objects is essential. Relatively simple shapes encompassing objects are used for collision determination, and for complex shapes, a combination of these shapes is used to approximate the object. The simplest shape is "①" because it can judge efficiently simply by calculating the distance from the positions of the center of "①." Additionally, there is a method for high-speed processing of collision detection between objects by "covering the object with any convex polyhedra."

The above is a collision detection method for stationary objects. In the case of moving objects, it is sufficient to perform the above collision detection process for objects at certain time intervals because the positions and postures of objects are static at that moment. However, for fast-moving objects, there is a possibility of "missing collision detection."

Figure. An Example of collision detection primitives. The blue polygons are the objects, and the red dotted lines are the shapes for collision detection.

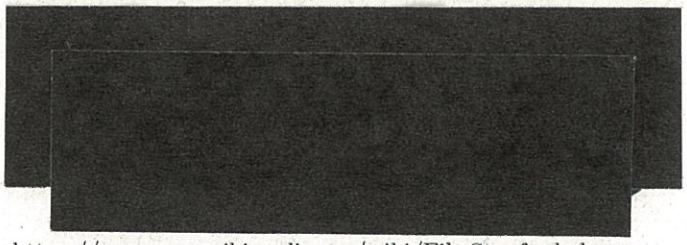
(1) Answer the adequate word for ①. (5 points)

(2) Related to "covering them with convex polyhedra," answer the smallest convex shape to contain an object. In addition, describe a specific example of it using a figure and sentences. Assume that the object is a random point cloud on a two-dimensional plane. (10 points)

(3) Penalty method and constrained method are known as physics-based simulation algorithms for resolving penetration between objects during collision. For either method, explain the specific calculation process using an example of sphere-to-sphere collision with figures and equations, etc. (10 points)

(4) Answer how to deal with the problem of "missing collision detection." It is recommended to use a diagram. (10 points)

[2] Suppose we have obtained the data for a 3D object as shown in the image below. The density of polygons is assumed to be sufficiently fine and variable. Based on this data, consider performing 2D or 3D rendering as in the question. Propose and explain the techniques to achieve each of the above. Use the keywords shown in parentheses. In addition to the above, you may use explanatory diagrams and mathematical formulas. [35 points]



https://commons.wikimedia.org/wiki/File:Stanford_bunny_qem.png

(1) The material of the object is made to look like a white plaster statue. (diffuse, Lambert's cosine low, BRDF) (7 points)
(2) Make the material of the object look like white marble. The texture is semitranslucent as if the incident light is internally scattered. (Subsurface scattering, BSSRDF, Monte Carlo simulation) (7 points)
(3) Apply an external force. Fracture deformation like pottery breaking on impact. (FEM, mesh, remesh) (7 points)
(4) The image is depicted as if it were placed in a room with light from the outside world coming in through a window. The light source environment data is acquired by a 360° camera. (Radiance, irradiance, rendering equations, image-based lighting) (7 points)
(5) Draw the object and make it look like it was drawn with a pencil. (Stylized rendering, hatching, stroke, mipmap) (7 points)

Question 5 [70 points]

In daily life, we rely on touch to explore the environment and recognize objects. Answer the following questions related to this capacity.

[1] List the five perceptual dimensions in the tactile perception of textures/materials. Consider what kind of information you can obtain when touching a surface. [15 points]

[2] In haptic exploration, six exploratory procedures (EP) are often used to obtain information on object properties, such as weight, shape etc. Explain the touch pattern of each EP and the associated object properties that the EP can obtain. [25 points]

[3] Some materials feel colder to touch than others of the same physical temperature. For example, at room temperature, metal feels typically colder to touch than wood. Please describe the heat transfer process during this hand-object interaction and the factors involved in this process. [30 points]

Question 6 [70 points]

[1] Figure 6-1 shows a semi-cylindrical shell made of a thin, uniform material with mass m[kg], radius r[m], and central angle π[rad]. The length in the direction perpendicular to the surface of the paper is uniform. If this semi-cylindrical shell is placed on a rough slope by the angle α[rad] from the horizontal as shown in Figure 6-2, with its axis perpendicular to the slope direction and the direction connecting the two ends of the arc of the semi-cylindrical shell horizontal (state of A shown by the thin double-dashed line), the semi-cylindrical shell rolls down the slope without slip by distance s[m] and comes to rest at an angle of ϕ[rad] to the horizontal from the point of contact at A (state of B shown by the thick solid line). Answer the following questions. Let the acceleration of gravity be g[m/s^2]. If there are quantities required other than the ones in the question, define and use them. [35]

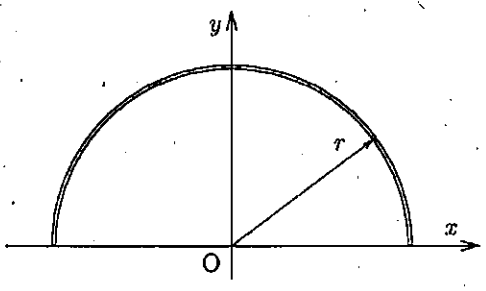


Figure 6-1

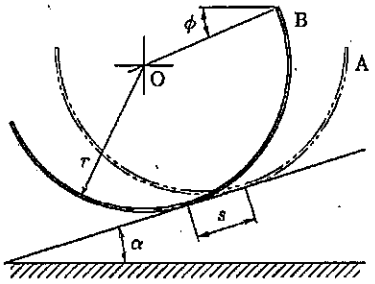


Figure 6-2

(1) This semi-cylindrical shell is placed face down on the x-axis with the y-axis superimposed on the object axis as shown in Figure 6-1. Find the coordinates (x_G, y_G) of the center of gravity G of the semi-cylindrical shell. Since the semi-cylinder is thin, the masses can be assumed to be equally distributed around the circumference of radius r. (10 points)

(2) Find the angle ϕ based on the forces and the moment of force acting on the semi-cylindrical shell on the slope. (10 points)

(3) Find the angle based on the gravitational potential of the semi-cylindrical shell. (15 points)

[2] There is a 2-DOF planar link shown in Figure 6-3, consisting of the link 1 and the link 2 with lengths l_1 and l_2, respectively, connected by revolutional joints, with point P as the end-effector. The base coordinate system is x_0-y_0, and other two coordinate systems x_1-y_1 and x_2-y_2 are set up as shown in the figure. The x_1 and x_2 axes are on the same line as link 1 and link 2, respectively, and α and β are the angles that each link makes with the x_0 and x_1 axes. Answer the following questions. [35]

(1) Determine the operation of transforming the position $(x_2, y_2)=(0, 0)$ of the end-effector P into the coordinate system x_1-y_1 using the homogeneous transformation matrix. (10 points)

(2) Using (1), find the matrix representation that transforms the position (x_2, y_2) of P into the base coordinate system x_0-y_0. (10 points)

(3) Find the conditions on α and β that maximize the manipulability of this planar link. (15 points)

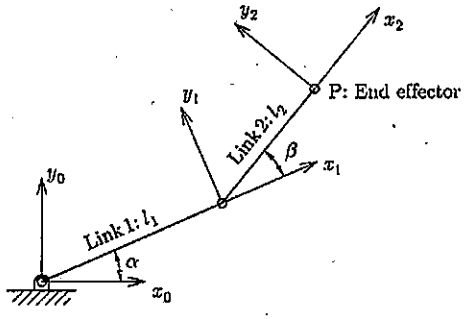


Figure 6-3