February 2023 Admissions

AY2023 Examination Questions for the Graduate School of Information Science and Engineering, Ritsumeikan University (Master's Program)

Major in Information Science and Engineering
Information Science and Engineering Course

【How to answer questions】

Please follow the instructions below and answer the questions.

Choose two questions from the common subjects and choose either the Computer Science section or the Human Information Science section.

In case choosing the Computer Science section, answer three questions from question ④~⑨.

In case choosing the Human Information Science section, choose one question either ⑩ or ⑪.

There will be two blank answer sheets in case choosing the Human Information Science section.

Common Subjects	①Linear Algebra ②Probability and Statistics ③Data Structure and Algorithms	
Specialized Subjects	Computer Science	④Computer Architecture ⑤Operating System ⑥Software Engineering ⑦Computer Networks ⑧Databases ⑨Artificial Intelligence
	Human Information Science	⑩Image Processing ⑪Artificial Intelligence

【Examination time】

9:30-11:30 (120minutes)

※Leaving the examination venue is not allowed during the examination time.

※In case you feel sick or need to go to the bathroom, let examination supervisors know by raising your hand.

【Notes】

(1) Use one answer sheet for one question.

(2) Fill out your examination number and name for all the answer sheets. Also, make sure to fill out all the other necessary sections such as the questions number column.

(3) Do not remove the staple of your answer sheets.

(4) Answer sheets with no names will be invalid. Do not take the question sheets and answer sheets with you after the examination.

Common Subjects

①Linear Algebra
②Probability and Statistics
③Data Structure and Algorithms

Choose two questions from the above.

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Common Subjects① Linear Algebra

Answer all the questions below with the derivation process.

Question 1. Given the following matrices A and B, find a that satisfies $|A| = |B|$.

$$A = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 6 & 4 & 3 & 4 \\ 4 & 2 & 2 & 3 \\ 2 & 1 & 1 & 2 \end{bmatrix}, \qquad B = \begin{bmatrix} a & 4 & 3 & 5 \\ 3 & 2 & 1 & 2 \\ 4 & 2 & 2 & 3 \\ 6 & 3 & 2 & 4 \end{bmatrix}$$

Question 2. Find the orthonormal basis for the following sequence of vectors by Gram–Schmidt orthonormalization.

$$\left\{ \boldsymbol{v}_1 = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}, \boldsymbol{v}_2 = \begin{bmatrix} 1 \\ 2 \\ 0 \end{bmatrix}, \boldsymbol{v}_3 = \begin{bmatrix} 2 \\ 2 \\ 1 \end{bmatrix} \right\}$$

Question 3. Given the following matrices C and D, find $(CD)^{75}$.

$$C = \frac{1}{2}\begin{bmatrix} 1 & -\sqrt{3} \\ \sqrt{3} & 1 \end{bmatrix}, \qquad D = \frac{1}{\sqrt{2}}\begin{bmatrix} -1 & 1 \\ -1 & -1 \end{bmatrix}$$

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Common Subjects②　Probability and Statistics

Answer all of the following questions with all calculation processes and ideas.

Question 1. For each of the following simultaneous probability density of the functions $f(x,y)$ of two continuous random variables X and Y, determine the values of the positive constants C_1, C_2, C_3.

Furthermore, find the peripheral probability density functions $f(x)$ of X and $f(y)$ of Y, and answer whether X and Y are independent of each other or not.

(1) $f(x,y) = \begin{cases} C_1 e^{-x-y}, & (x \geq 0 \text{ and } y \geq 0) \\ 0, & (\text{otherwise}) \end{cases}$.

(2) $f(x,y) = C_2 e^{-|x|-|y|}$.

(3) $f(x,y) = C_3 e^{-x^2-y^2} + C_3 e^{-(x-1)^2-(y-1)^2}$.

Question 2. Suppose 10 samples $\{x_1, x_2, \cdots, x_{10}\}$ are obtained from a population following a normal distribution $P(x|\mu,\beta) = \sqrt{\frac{\beta}{2\pi}} e^{-\frac{\beta}{2}(x-\mu)^2}$ with parameters of mean μ and precision (inverse of variance) β.

(1) Find the log-likelihood function $L(\mu,\beta)$.

(2) Find the parameter (μ,β) that maximizes the log-likelihood function $L(\mu,\beta)$.

(3) If the parameter β follows a gamma distribution $P(\beta|b,\kappa) = \frac{\kappa^\kappa}{b^\kappa \Gamma(\kappa)} \beta^\kappa e^{-\kappa\beta/b}$, show that the peripheral distribution $P(x|\mu,b,\kappa) = \int_0^\infty P(x|\mu,\beta)P(\beta|b,\kappa)d\beta$ is $P(x|\mu,b,\kappa) = \frac{\Gamma\left(\kappa+\frac{1}{2}\right)}{\Gamma(\kappa)} \sqrt{\frac{b}{2\pi\kappa}} \left(1 + \frac{b}{2\kappa}(x-\mu)^2\right)^{-\kappa-\frac{1}{2}}$ of X,

where $\Gamma(\kappa) = \int_0^\infty u^{\kappa-1} e^{-u} du$ is the gamma function.

(4) Answer which kind of distribution the peripheral distribution $P(x|\mu,b,\kappa) = \frac{\Gamma\left(\kappa+\frac{1}{2}\right)}{\Gamma(\kappa)} \sqrt{\frac{b}{2\pi\kappa}} \left(1 + \frac{b}{2\kappa}(x-\mu)^2\right)^{-\kappa-\frac{1}{2}}$, derived in (3), approaches, as $\kappa \to \infty$.

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Common Subjects③ Data Structure and Algorithms

This question consists of 2 pages. Answer all the questions below.

Question 1.

The quicksort procedure for an array, whose length is n, is as follows.

1. Pick a reference value *p*, called a pivot, within the specified range.
2. Partition the range. Reorder its elements, while determining a point of division, so that all elements with values less than the pivot *p* come before the point of division, while all elements with their values greater than or equal to the pivot *p* come after the division.
3. Recursively apply the quicksort to both the subrange up to the point of division and to the subrange after it, until there is only one element in the division.

Please answer the following questions.

(1) Answer the name of a sorting algorithm that uses recursion as same as quicksort.

(2) Write appropriate words or formulas in the blanks [(a)] to [(d)] in the following text regarding the maximum time complexity of quicksort.

The worst case for quicksort is when the [(a)] results in n-1 elements remaining in one set and an empty set in the other. This happens when the [(b)] or [(c)] element is chosen as the pivot p.
Assume that such a situation occurs every [(a)],
Q_n = [(d)],
where Q_n is the number of comparisons to sort the entire array whose length is n.

(3) For the range specified by *left* and *right* of the array x to be sorted
{ x[*left*], x[*left* +1], …, x[*right* - 1], x[*right*] },
the function that performs quicksort is defined as follows:
quicksort (x, *left*, *right*).
The function that partitions the range of the array into two parts by pivot and returns the position where the pivot falls is defined as follows:
partition (x, *left*, *right*).
The quicksort algorithm can be written using these functions as shown in Figure 1.

```
quicksort (x, left, right) {
    if (left < right) {
        p ← partition (x, left, right) ;
        quicksort (x, left, p - 1) ;
        quicksort (x, p + 1, right) ;
    }
}
```

Figure 1 The pseudocode of quicksort

Using this as a reference, write the following function that recursively finds the K-th smallest value in an array with less computation than quicksort.
selectKth (x, *left*, *right*, K),
where x is an array with n elements. K must be a value within the range of the subscripts of the array x, and the array subscripts start from 1. Also, the order of the array elements may be changed, and this function should be called as follows:
selectKth (x, 1, n, K).
Note that this function returns a value using the return statement.

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* This question consists of 2 pages.

Question 2.

Suppose that a singly-linked list which stores integers as data is represented as Figure 2. Answer the following questions about this list.

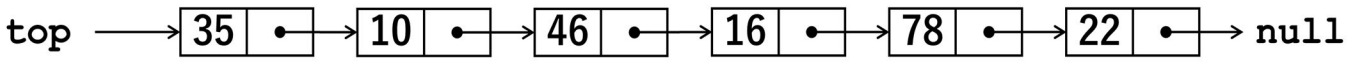

Figure 2 A diagram of a singly-linked list

(1) Table 1 below shows the list in Figure 2 in tabular form. When the value of top, which indicates the address of the top element of the list, is 1008, write the appropriate numbers in blanks [(a)] to [(f)] of table 1.

Table 1 The list in Figure 2 in tabular format

address	data	next
[(a)]	10	1032
1008	[(b)]	1000
[(c)]	16	[(d)]
1024	78	[(e)]
1032	[(f)]	1016
1040	22	null

(2) Figure 3 is the pseudocode of the function searchMax() which returns the position where the maximum value is stored in the given list. The position where the maximum value is stored is to be stored in variable m. The data can be referenced by adding .data to the element it points to, like top.data, and the next element can be referenced by adding .next to the element it points to, like top.next.

Write pseudocode that applies to (g) and (h) in the pseudocode shown in Figure 3.

```
searchMax (top) {
    x ← top ;
    m ← top ;
    while ( x != null ) {
        if ( [ (g) ] > x.data ) {
            m ← x ;
        }
        [ (h) ]
    }
    return (m) ;
}
```

Figure 3 The pseudocode for searching for the maximum value

Specialized Subjects

Computer Science

④Computer Architecture
⑤Operating System
⑥Software Engineering
⑦Computer Networks
⑧Databases
⑨Artificial Intelligence

In case choosing the Computer Science section, answer three questions from question ④～⑨

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Computer Science④ Computer Architecture

Answer all the questions below.

Question 1.

Explain the differences between a direct-mapped cache, a fully associative cache, and a set associative cache.

Question 2.

Answer the number of tag, index, and offset bits of the following three caches when the size of the address space is 2^{32} bytes, the cash memory size is 32K bytes, and the cache block size is 32 bytes. Also, show the calculation process.

A) A direct-mapped cache
B) A fully associative cache
C) A 2-way set associative cache

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Computer Science⑤ Operating System

Answer all the questions below.

Question 1. Explain the words "process" and "thread" of the process-thread model.

Question 2. Most memory management techniques are based on the concept of locality of reference. It can be classified into temporal locality and spatial locality. Explain their characteristics.

Question 3. Thrashing may occur on operating systems adopting virtual memory. Explain this phenomenon and the circumstances in which it occurs.

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Computer Science⑥ Software Engineering

Answer all the questions below.

Question 1.

What do the following technical terms mean in software testing?

(1) Unit testing

(2) Integration testing

(3) Acceptance testing

Question 2.

What are relationships between a class and its instance in object-oriented programming?

Question 3.

What is the purpose of adaptive maintenance for software systems?

Question 4.

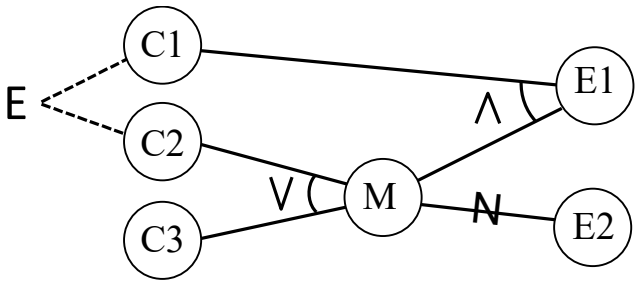
Consider a decision table derived from the Cause-Effect graph as shown below. Answer the following questions:

(1) What is the minimum number of test cases generated by a column of the decision table?

(2) How many test cases of the generated ones should be executed when checking if effect E1 can be true in the decision table?

(3) How many test cases of the generated ones should be executed when checking if effect E2 can be true in the decision table?

Note that "E" connected by dotted lines means the exclusive constraint in the Cause-Effect graph.



Cause-Effect graph

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Computer Science⑦ Computer Networks

This question consists of 2 pages. Answer all the questions below.

Question 1. For the descriptions regarding computer networks from (1) to (6) below, complete each description by selecting correct answers from options inside rectangles if one exists. Or if you find no suitable options, you may answer by writing suitable keywords or phrases. Assume that the same term will be placed in all enclosures with the same problem symbol.

(1) Q(a) ① ITU ② IETF ③ IEEE ④ IrDA is the abbreviation for the organization, headquartered in the United States of America, which is a society for electrical and electronic engineering and is engaged in standardization activities related to communications, electronics, and information engineering and related fields in English.

(2) Slotted Q(b) ① CDMA ② CSMA/CA ③ CSMA/CD ④ ALOHA , a media control method, improves throughput by introducing discrete time slots to Pure Q(b) . The theoretical maximum throughput of Slotted Q(b) , expressed with three digits of precision, is about 36.8%, while that of Pure Q(b) , expressed with the same precision, is about Q(c) ① 7.90 ② 12.2 ③ 16.3 ④ 18.4 %.

(3) In the OSI Basic Reference Model (or the OSI Reference Model), the top layer provided by an intermediate open system (or an intermediate system) is the Q(d) ① physical ② data link ③ network ④ transport layer. In an IP (Internet Protocol) network, the device corresponding to an intermediate open system is called an IP Q(e) ① switching hub ② router ③ bridge ④ repeater .

(4) For an IPv4 (Internet Protocol version 4) address that is denoted as 10.162.42.254 in dotted decimal notation, the addressing of this IP network is a class Q(f) ① A ② B ③ C ④ D ⑤ E . Assuming a dotted decimal subnet mask of 255.255.252.0, the maximum number of unique IP addresses for unicast communication in this network would be Q(g) ① 162 ② 1022 ③ 1624 ④ 2254 .

(5) The first four bits of the IP header indicate the IP version number. This means that the field is Q(h) ① 0001 ② 0100 ③ 0110 ④ 1001 in binary for IPv4 header. Of the respective IP headers, an IPv4 header and an IPv6 (Internet Protocol version 6) fixed header, the checksum field is present Q(i) ① in IPv4 one only ② in IPv6 one only ③ both in IPv4 one and in IPv6 one .

(6) The communication protocol Q(j) ① RSVP ② RTP ③ RTSP ④ RTCP is used to guarantee the quality of communication paths on IP networks by reserving bandwidth from the source to the destination in advance.

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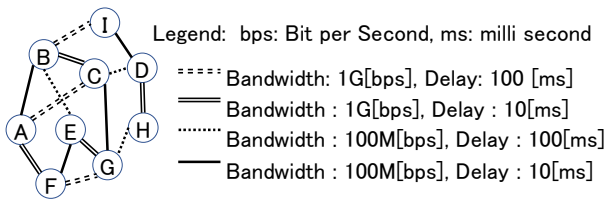
* This question consists of 2 pages.

Question 2. The figure in the right side shows a network named "N." The letter inside the circle denotes a node and its name. The line between two nodes denotes a link between the nodes. The specifications of each link are denoted in the figure legend. You can suppose that the delay time for interlink transfer at a node may be ignored in this question Q2.



(1) Define the reasonable inter-node link cost as positive distance metric to minimize the delay time and show the value of the costs for the network "N."

(2) - Describe the Dijkstra's algorithm by demonstrating all procedures on the network "N" with the link costs calculated in the previous problem (1) for determining all shortest path from node "A" to other nodes. Skipping any step or omitting the explanation of each step is not allowed. The shortest paths of multiple nodes that have the same cost from node "A" may be obtained in a single step (this means that, as long as you do not violate the algorithm, you do not have to restrict the shortest path to be obtained in a single step to a single node).
- Also, answer which node(s) have the maximum delay in these settings and indicate their delays.

(3) Using the same procedures from (1) through (2),
- find a single path to each node from node "A" on the network "N" that maximizes the communication bandwidth of that path and also find the delay time and the communication bandwidth for each path. If there are multiple links with the same bandwidth, choose the link with the lowest delay.
- Also, find all path(s) that have the maximum delay in these settings and indicate their delays.

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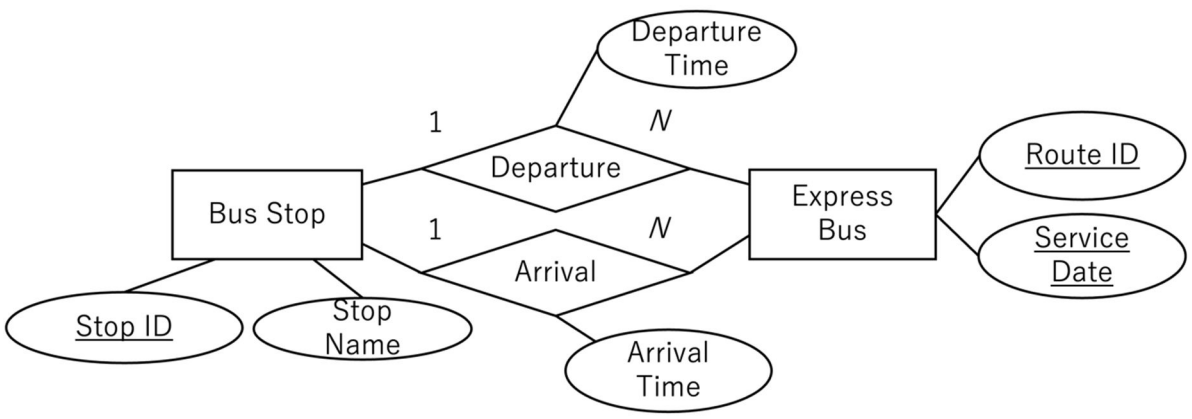
Computer Science⑧ Databases

This question consists of 2 pages. Answer all the questions below.

Question .

For the following explanations on Databases from (i) to (iii), choose the most appropriate word for the boxes (1) to (13) from the options and answer with the symbols shown in alphabetic letters. Moreover, answer with numerical values for (14) and (15). Note that some unrelated options are included, and some of the letters are omitted. Assume that the same word is enclosed in the box with the same number.

(i) In designing a database for express bus schedule management, the following diagram created from user requirements as a conceptual schema is called (1). The (1) consists of rectangles representing (2) and diamonds representing (3). Also, the diagram includes ellipses named (4) to describe the properties of (1) and (2).



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* This question consists of 2 pages.

(ii) The above diagram creates relation ① and [(5)] of the following items. Note that departure and arrival time may vary according to service dates even on the same route.

① Bus_Stop (Stop_ID, Stop_Name)
② Express_Bus (Route_ID, Service_Date)
③ Express_Bus (Route_ID, Service_Date, Departure_Stop_ID, Arrival_Stop_ID)
④ Express_Bus (Route_ID, Service_Date, Departure_Stop_Name, Arrival_Stop_Name)
⑤ Express_Bus (Route_ID, Service_Date, Departure_Stop_ID, Departure_Time, Arrival_Stop_ID, Arrival_Time)
⑥ Schedule (Departure_Time, Arrival_Time)
⑦ Schedule (Service_Date, Departure_Time, Arrival_Time)
⑧ Schedule (Route_ID, Departure_Time, Arrival_Time)
⑨ Schedule (Departure_Stop_ID, Arrival_Stop_ID, Departure_Time, Arrival_Time)

The created relations are not second-normal forms because there are attributes that are not [(6)] functional dependent on the [(7)]. To satisfy the second-normal form, the relations are transformed as follows.

Bus_Stop (Stop_ID, Stop_Name)
Express_Bus1 (Route_ID, [(8)])
Schedule1([(9)], Departure_Time, Arrival_Time)

To calculate the total number of express buses that depart on the morning of April 1st in 2023, the SQL statement is as follows.

SELECT [(10)]
FROM Schedule1
WHERE Departure_Time [(11)] '2023-04-01 00:00:00' AND '2023-04-01 12:00:00');

(iii) There are two evaluation criteria for information retrieval: [(12)], a fraction of correct documents among retrieval results, and [(13)], a fraction of retrieved results among all the correct documents. For example, in retrieving a product at the online shop storing 100 products, it returns 30 products, 15 of which match the query, and stores 10 correct products other than the retrieval results. In this case, [(12)] is [(14)], and [(13)] is [(15)].

[Options]

a	entity types	b	precision	c	CODASYL model	d	foreign key
e	LIKE	f	fully	g	candidate key	h	accuracy
j	partially	k	recall	l	set types	m	attributes
n	super key	o	bachman diagram	p	BETWEEN	q	weak entity types
r	TOTAL(*)	s	transitively	t	record types	u	sensitivity
v	relationship types	w	COUNT(*)	x	ER diagram	y	Route_ID
z	Service_Date	A	Route_ID, Service_Date	B	Departure_Stop_Name, Arrival_Stop_Name	D	Departure_Stop_ID, Arrival_Stop_ID
E	② and ⑨	G	③ and ⑨	H	③ and ⑧	J	③ and ⑦
L	③ and ⑥	M	④ and ⑦	Q	④ and ⑧	R	⑤

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Computer Science⑨ Artificial Intelligence

This question consists of 2 pages. Answer all the questions below.

Question. For the following explanations of Artificial Intelligence (AI) from (i) to (v), choose the most suitable word or number for the boxes (1) to (15) from the options shown below each explanation and answer with the symbols shown in alphabetic letters. Note that some unrelated options are included. Assume that the same word is enclosed in boxes with the same number.

(i) The method of decomposing the entire given problem into multiple subproblems and finding a solution to the entire problem while memorizing the solution to each subproblem is called [(1)] . In graph G_1 in Fig.1, the nodes are states A_t、B_t、C_t at time t, and the numbers along edges are the evaluation values (gain) obtained when performing that state transition. In this graph G_1, the path from node S to G that maximizes the sum of the evaluation values of the traversed edges is found by [(1)] . Then, the evaluation value to be memoized to node B_2 is [(2)] , and the sum of the evaluation values of the edges in the obtained path is [(3)] .

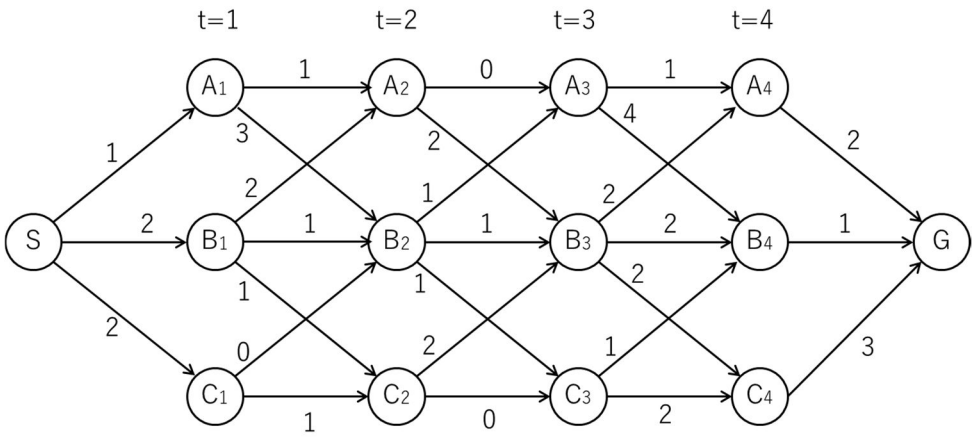

Fig.1 Graph G_1

【Options for (i)】

a	3	b	4	c	8	d	10
e	11	f	A* Algorithm	g	Dynamic Programing	h	mini-max method

(ii) A certain product X is produced in two factories, and 80% of its total output is produced in factory A and 20% in factory B. However, 2% of the products from Factory A are defective and 3% of the products from Factory B are defective. Note that products that are not defective must be considered good products. Then, answer the following questions. Notice that the options are shown as values to three decimal places.

1. The probability that a product X is good and produced at factory B is [(4)] .
2. The probability that a product X is defective is [(5)] .
3. Given that a product X is defective, the probability that it is produced in factory A is [(6)] .

【Options for (ii)】

a	0.006	b	0.016	c	0.022	d	0.050
e	0.194	f	0.273	g	0.727	h	0.970

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* This question consists of 2 pages.

(iii) Consider a normal form game represented by the payoff matrix in Table 1. In the payoff matrix, the left value of each cell is the payoff of Player A, and the right one is the payoff of Player B. Assume that each player acts rationally. When a pair of Players' actions are optimal responses to each other's actions, the pair is called [(7)] . In the game in Table 1, [(7)] is when the actions of Player A and Player B are [(8)], respectively. Also, when each Player takes the action with the highest payoff regardless of the other' s action, the pair of the actions is called [(9)] .

Table 1 Payoff matrix

Player A \ Player B	b_1	b_2
a_1	(-2, 3)	(3, 4)
a_2	(-1, 1)	(4, 0)

【Options for (iii)】

a	dominant strategy equilibrium	b	national equilibrium	c	mini-max equilibrium	d	Nash equilibrium
e	a1, b1	f	a1, b2	g	a2, b1	h	a2, b2

(iv) Machine learning methods in which the relationship between inputs and outputs is learned from training data given a teacher signal, which is the correct output, are called [(10)] . Among the problems handled by [(10)] , the problem of learning a continuous functional relationship that returns a real value for a vector representing the input data is called [(11)] . Also, [(12)] is the method used to evaluate the generalization performance of the learner. For example, there is a method in which the data set is divided into K pieces, K-1 of which are training data and the remaining one set is test data, and the evaluation is repeated K times so that all K pieces become test data one by one, and the overall evaluation value is obtained by averaging the obtained K evaluation values.

【Options for (iv)】

a	classification problem	b	regression problem	c	clustering	d	reinforcement learning
e	transfer learning	f	cross-validation	g	one-hot vector	h	supervised learning

(v) Consider converting a logical formula to clause form. When removing the implication sign, $P \rightarrow Q$ is replaced by [(13)] . Also, applying de Morgan's law to $\neg(P \wedge Q)$ gives [(14)] , and applying the distributive law to $P \vee (Q \wedge R)$ gives [(15)] .

【Options for (v)】

a	$P \equiv Q$	b	$\neg P \vee Q$	c	$\neg P \vee \neg Q$	d	$\neg P \wedge \neg Q$
e	$P \wedge \neg Q$	f	$(P \wedge Q) \vee (P \wedge R)$	g	$(P \vee Q) \wedge (P \vee R)$	h	$P \vee Q \wedge R$

Specialized Subjects

Human Information Science

⑩Image Processing
⑪Artificial Intelligence

In case choosing the Human Information Science section, choose one question either ⑩ or ⑪

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Human Information Science⑩ Image Processing

This question consists of 2 pages. Answer all the questions below.

Question 1.

100	105	100
95	75	50
45	50	55

is a 3 by 3 image. The horizontal direction points to the right and the vertical direction points downward. For the center pixel,

(1) Compute the horizontal derivative and the vertical derivative, where Ix(0,0)=(I(1,0)-I(-1,0))/2 and Iy(0,0)=(I(0,1)-I(0,-1))/2.

(2) Compute the second derivative for the horizontal direction, where Ixx(0,0)= I(1,0)-2I(0,0)+I(-1,0)

(3) compute the second derivative for the vertical direction, which is defined in the same manner as the horizontal direction.

(4) compute the second derivative for both the horizontal and vertical directions,

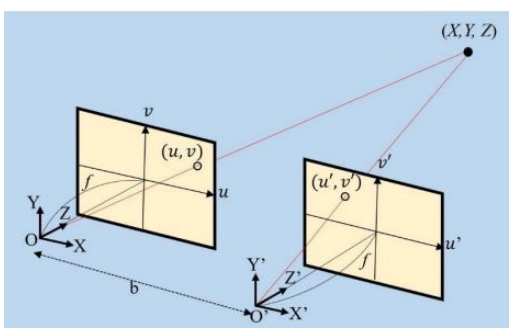
which is defined as Ixy(0,0)=(Ix(0,1)-Ix(0,-1))/2= (I(1,1)-I(-1,1)-I(1,-1)+I(-1,-1))/4

Question 2.

Suppose we create a 2D Gaussian filter from the 2D Gaussian function G(x,y)=A*exp(-(x*x+y*y)/2) using only 8 bits for each value in the filter. Determine A first. Suppose that the filter is B×B pixels. Determine B. For your convenience, exp(-1/2)≒0.6, exp(-2)≒0.135 , exp(-4.5)≒0.0111, exp(-8)≒0.0003.

Question 3.

The figure shows a parallel stereo, where the distance between the two cameras is b, and the point on the left image (u,v) corresponds to the point on the right image (u',v). Determine X, Y and Z. It is known that in parallel stereo, axis u and axis u' are collinear and parallel to axis X, and axis v and axis v' are parallel to axis Y. The origin of (u,v) coordinates is on the Z axis, and two cameras have exactly the same intrinsic parameters. We also assume that f is known and given in pixels.



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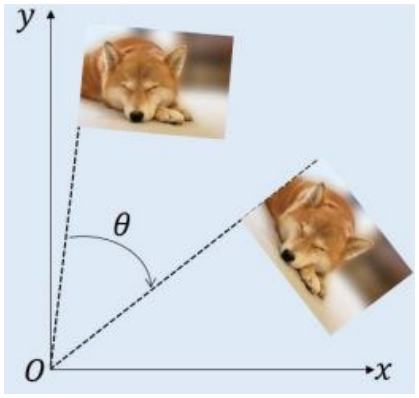
* This question consists of 2 pages.

Question 4.

As shown in the figure, after rotating the image clockwise by 30 degrees, it is further translated by 10 in horizontal direction and 20 in the vertical direction. The new coordinates can be expressed by

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix}$$

Determine a, b, c, d, e and f.



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Human Information Science⑪ Artificial Intelligence

Answer all the questions below.

Question .

(1) Consider two strings, "**xyzxyz**" and "**xyxzyz**". Calculate the *edit distance* between these two strings using *dynamic programming*. The values determined in *memoization* to perform dynamic programming (i.e., edit distances between substrings) should all be shown in a matrix form.

(2) Consider a symbolic artificial intelligence (AI) system that proves a logical inference problem in propositional logic. Show that the conclusion R∨S is obtained when the AI system has knowledge that P ∧ Q, P → R, and Q → S using a *resolution refutation proof*, i.e., a proof by contradiction using resolution. In addition, please show a proof tree.

(3) Answer the following questions.

(3-1) Probability theory is important in machine learning. Please explain "marginalization" and the "multiplication theorem" in probability theory with equations and text descriptions.

(3-2) What is context analysis in natural language processing? Please explain it with example sentences.

(3-3) What is an activation function in neural networks? Please explain it with equations and text descriptions.

(3-4) Most reinforcement learning methods are developed based on the assumption of a Markov decision process (MDP). What is a MDP? Please explain it with a probabilistic graphical model, equations, and text descriptions.