Ritsumeikan University Graduate AY2023 Entrance Examination

Master's Program

Graduate School of Information Science and Engineering

Advanced Information Science and Engineering Major

Admissions	Course	Examination	Major Subjects (Common Subjects・Specialized Subjects)	
			page	Notes
Regular Admissions (English-based Program)	Information Science and Engineering	August	P. 1～	
		February	P. 23～	
		February (September 2024 Enrollment)	P. 23～	
International Student Admissions (English-based Program)		July (September 2023 Enrollment)		
		August		
		December		
In-University Advancement Admissions (English-based Program)		July		
		February (September 2024 Enrollment)		

【How to read the front cover page】
×…Those for which the entrance examination questions were not created due to reasons such as the entrance examination not being conducted, or those for which the examination questions are not disclosed.
Diagonal line…The test designed by each couse(a written test) has not been conducted.

Ritsumeikan University Graduate School

AY2023 Entrance Examination

Doctoral Program

Graduate School of Information Science and Engineering

Advanced Information Science and Engineering Major

Written Examination is not conducted for the Doctoral Program.

August 2023 Admissions

AY2024 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. Find the real numbers a, b, c, and d in the equation $ax + by + cz + d = 0$ that represents the plane passing through three points $P_1(1,3,5)$, $P_2(-3,0,1)$, and $P_3(6,2,-4)$.

Question 2. Solve the following system of equations.

$$\begin{cases} 5x + 4y + 3z = 1 \\ 2x - 2y + z = -11 \\ -3x + y - 2z = 9 \end{cases}$$

Question 3. Answer the following, given $A = \begin{bmatrix} 1 & 3 \\ -1 & -2 \end{bmatrix}$.

(1) Find A^{-1}.

(2) Find A^{19}.

(3) Find $A^{25} + 7A^{15} - 3A^{5}$.

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Common Subjects② Probability and Statistics

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

Question 1. Answer the following questions for two continuous random variables X and Y.

(1) Explain the following statement mathematically.
"Random variables X and Y are mutually independent".

(2) Explain the following statement mathematically.
"Random variables X and Y are uncorrelated".

(3) For each of the following statements, if it is correct, prove it.
If not, give one example that follows it and one example that does not.

① "If random variables X and Y are mutually independent, they are uncorrelated."

② "If random variables X and Y are uncorrelated, they are mutually independent."

Question 2. Answer the following questions for two continuous random variables, X and Y, which follow a standard normal distribution, and are mutually independent.

(1) Find the probability density function of the random variable $Z = X + Y$.

(2) Find the probability density function of the random variable $V = Y^2$.

(3) Find the probability density function of the random variable $T = X/\sqrt{V} = X/\sqrt{Y^2}$.

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Common Subjects③ Data Structure and Algorithm

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

Question 1.

Figure 1 presents the pseudo-code for an insert function, which is responsible for adding a given integer value in a binary search tree. Additionally, it also includes a visit function, which traverses each node of the binary search tree and displays the value stored within each node. In this context, the create() function is utilized to create a node with the given value in the binary search tree, while the print() function is employed to display the stored value in a specific node. The value stored in the node can be accessed through node.value, and node.left and node.right correspond to the left child and right child of the node, respectively. Answer the following questions.

(1) Illustrate the final resulting binary search tree, following the notation for a binary search tree in Figure 2, created when the sequence S = {3, 7, 1, 5} is given to the insert function in order.

(2) Show the order of the values displayed when the node corresponding to the root of the binary search tree in Figure 2 is given to the visit function.

(3) The time complexity of the insert function depends on the order of the data in the given sequence. Answer the best-case and worst-case time complexities for any data in order notation using the number of data *n*.

(4) Rotation is a proposed operation to convert the tree structure so that the difference in height between the left and right subtrees of all nodes in a binary search tree is within 1. Illustrate the binary search tree obtained by making a single rotation to the right of the root for the binary search tree in Figure 2.

```
1: function insert(Node node, int key):
2:     if node = null then
3:         return create(key)
4:     end
5:     else if key < node.key then
6:         node.left ← insert(node.left, key)
7:     end
8:     else if key > node.key then
9:         node.right ← insert(node.right, key)
10:    end
11: end
13:
14: function visit(Node node):
15:    if node != null then
16:        print(node.key)
17:        visit(node.left)
18:        visit(node.right)
19:    end
10: end
```

Figure 1: Pseudo-codes related to a binary search tree

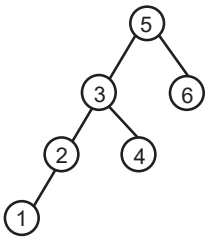

Figure 2: An example of a binary search tree

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* This section consists of 2 pages.

Question 2.

Given an array A that contains n integer values, answer the following questions regarding the algorithm for sorting in ascending order according to steps 1 to 3. The array has n elements, and each element at the i-th index can be referenced as A[i], where i ranges from 0 to n-1.

Step 1: Repeat Steps 2 and 3 for i = 0 to n-1

Step 2: Find the index p of the element with the smallest value among A[i], … , A[n-1]

Step 3: Swap A[i] with A[p]

(1) Illustrate the entire process of sorting the array A = {3, 4, 2, 1}.

(2) Answer the name of this algorithm.

(3) Answer average-case and worst-case time complexities for any array in order notation using the number of elements n.

(4) When sorting data with two or more elements that have the same value, a sorting algorithm that preserves the order of the elements before and after sorting is called stable sort. Answer "yes" if this algorithm is a stable sort, and "no" otherwise.

(5) Answer a name of the sorting algorithm that has a lower worst-case time complexity than this algorithm.

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.

Answer the following questions about a RISC processor. Here, ISE2023, in the following questions, is a fictitious RISC processor. ISE2023 has general-purpose registers R1 to R2, and has the instruction set shown in Table 1. In the table, "Rd", "Rs", and "Rt" are arbitrary registers among R1 to R2, "imm" is an immediate operand (signed integer), and "label" is a label pointing to an address of arbitrary instruction word.

Table 1

Instruction	Assembly Coding	Functionality
ADD	ADD Rd, Rs, Rt	Rd ← Rs + Rt
ADDI	ADDI Rd, Rs, imm	Rd ← Rs + imm
BNE	BNE Rs, label	Branch to label if Rs ≠ 0
LI	LI Rd, imm	Rd ← imm

(1) Briefly describe the relationship between the initial value of R1 and the obtained value in R2 in the program given by the assembly code for ISE2023 shown in Fig. 1. Here, we assume that the initial value of R1 is a positive integer and that no overflow occurs during the calculation.

(2) Find the number of cycles required to execute the program in Fig. 1 and the CPI (cycles per instruction) for this case (Find the CPI down to one decimal place). Here, the number of cycles required for the BNE instruction is always four, and that needed for every other instruction is one. Let the initial value of R1 be ten.

(3) Find the number of required cycles and the CPI value when the program in Fig. 2 is executed under the same conditions as (2).

(4) State the condition of the initial value of R1 with which the same result as the program in Fig. 1 can be obtained with the program in Fig. 2.

(5) What is it called when the program in Fig. 1 is replaced with the program in Fig. 2?

```
BEGIN:  LI   R2, 0
LOOP:   ADD  R2, R2, R1
        ADDI R1, R1, -1
        BNE  R1, LOOP
END:
```

Fig. 1

```
BEGIN:  LI   R2, 0
LOOP:   ADD  R2, R2, R1
        ADDI R1, R1, -1
        ADD  R2, R2, R1
        ADDI R1, R1, -1
        BNE  R1, LOOP
END:
```

Fig. 2

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Computer Science⑤ Operating System

Answer all the questions related to virtual memory below.

Question 1.
Explain what virtual memory is and describe its possible merits.

Question 2.
Suppose two processes are running on different virtual address spaces and they would exchange some data. Describe a method related to address spaces to achieve this, and also describe why this method is not needed when different threads that belong to the same process exchange data.

Question 3.
Let us translate a 4-byte virtual address in base 16, 0x1234ABCD, into the corresponding physical address. The first 3 bytes are the block number, and the last 1 byte is the offset. Describe the process of this translation, including which part is done by software and which part is done by hardware. Note that we assume a single-layer structure for the address translation table. If you need some additional values that are not written in the question, you may assume they are arbitrary.

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Computer Science⑥ Software Engineering

Answer all the questions below.

Question 1. Explain the shortcomings of the waterfall model.

Question 2. Explain the difference between stubs and drivers in software testing.

Question 3. Explain the difference between branch coverage and conditional coverage in software testing.

Question 4. Explain message passing in object-oriented programming.

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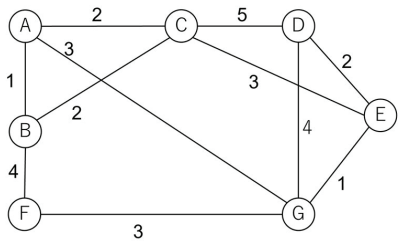
Computer Science⑦ Computer Networks

Answer all the questions below.

Question 1.

Using Dijkstra's algorithm, find the shortest path for routing packets from node A to every other node in the network below. The number near the link denotes the distance for the link. Complete the table below, showing each step of the algorithm. In the second column of the table, write the shortest path set S of nodes to which the algorithm has the shortest path and (destination node, next node, distance). Here, the destination node is the new node in the shortest path set, the next node is the next-hop node from node A to reach the destination node, and the distance is the shortest path distance from node A to the destination node.



Step	S, (Destination node, predecessor, distance)
1	S={A}, (A, -, 0)
2	S={A,B}, (B,A,1)
3	
4	
5	
6	
7	

Question 2.

For each description regarding computer networks, in the answer sheet write T if it is true and F if it is false.

(1) In the DNS, the record which specifies a mail server to handle a domain's email is called an NS record.
(2) One weakness in Link State (LS) routing algorithms is the "count-to-infinity" problem.
(3) Every datalink layer protocol requires a MAC channel access protocol.
(4) One new feature supported in IPv6, but not IPv4, is IP fragmentation.
(5) On the Internet, each Autonomous System (AS) communicates with other ASs using BGP.
(6) A bridge is a link-layer (layer 2) device.
(7) Cyclic Redundancy Check (CRC) is a powerful error correction code.
(8) The Routing Information Protocol (RIP) uses the Bellman-Ford algorithm.
(9) DHCP is an application-layer protocol.
(10) 10.13.159.125 is a private IP address.

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Computer Science⑧ Databases

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

Question 1. For the following explanations on database design, choose the most appropriate word from the choice list and answer with the symbols shown as letters [A] – [L]. Note that some unrelated options are included. Assume that when the same number is enclosed in the box, the answer corresponds to the same letter.

Database design is done in the following process:
1st stage (1): We identify the purpose of the database, the business information targeted by the database, and we extract and organize the (2) from users.
2nd stage (3) schema design: We describe the information structure of the database, assuming an ideal future information system and database, independently of the data model and schema used in the actual database.
3rd stage (4) schema design: We describe a (4) schema which is the (4) structure of the information needed to build a database in the database management system we use.
4th stage (5) schema design: We describe the (5) structures required to store and manage the database data.

Choice list

[A] conceptual definition	[B] requirement definition	[C] purpose	[D] requirement
[E] work	[F] knowledge	[G] requirement	[H] conceptual
[I] database	[J] logical	[K] information	[L] physical

Question 2. Select all among the following (a) – (f) that have a functional dependency between the attributes of the relation R consisting of the 6 tuples.

Relation R

X	Y	Z
10	AAA	4
10	AAA	4
20	BBB	2
20	BBB	2
30	BBB	6
30	BBB	6

(a) X → Y
(b) X → Z
(c) Y → Z
(d) Y → X
(e) Z → X
(f) Z → Y

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* This section consists of 2 pages.

Question 3. Describe the result of the join operation P $\bowtie_{B<C}$ Q and P $\bowtie_{B=D}$ Q for the two relations P and Q below.

P

A	B
-1	1
0	3
1	2

Q

C	D	E
2	3	1
2	2	4
3	3	4

(1) P $\bowtie_{B<C}$ Q

(2) P $\bowtie_{B=D}$ Q

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Computer Science⑨ Artificial Intelligence

This section 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 when the same number is enclosed in the box, the answer corresponds to the same letter.

(i) Consider three algorithms, the optimal search (Dijkstra's algorithm), the best-first search, and the A* algorithm, that solve the shortest path problem from an initial node to a destination node. These algorithms have different criteria for sorting the nodes to be explored in order to determine the next node to be explored. Let $g(s)$ be the sum of the costs on the optimal path from the initial node to node s, $h(s)$ be the sum of the costs on the optimal path from node s to the destination node, and $f(s)(= g(s) + h(s))$ be the cost of the optimal path through node s. In this case, the nodes to be explored are sorted in order of decreasing [(1)] in the optimal search, [(2)] in the best-first search, and [(3)] in the A* algorithm. Note that the symbol ^ denotes an estimated value and, for example, $\hat{y}(s)$ denotes the estimated value of function $y(s)$.

【Options for (i)】

a	$g(s)$	b	$h(s)$	c	$f(s)(= g(s) + h(s))$	d	$\hat{g}(s) - g(s)$
e	$\hat{g}(s)$	f	$\hat{h}(s)$	g	$\hat{f}(s)(= \hat{g}(s) + \hat{h}(s))$	h	$\hat{h}(s) - h(s)$

(ii) Consider using dynamic programming to find the edit distance between two strings. In this case, the edit distance to the substrings of the target strings is [(4)] for recording and used in the following calculations. The edit distance from string "abebc" to string "babbe" is [(5)], and the number of "replace" operations in this edit operation is [(6)]. Note that the edit distance is the minimum number of editing operations required to transform one string into the other, with each editing operation being the insertion, deletion, or replacement of one character.

【Options for (ii)】

a	0	b	1	c	2	d	3
e	4	f	memorized	g	maximized	h	decentralized

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(iii) Clustering is the classification of a collection of data into several groups according to the similarity between the data, and is categorized as [(7)] in machine learning. In the [(8)], one of the deterministic clustering methods, classification is performed by repeatedly classifying data based on the distance to each cluster representative point and updating the coordinates of each cluster representative point. In this method, the objective function, expressed as the sum of the squared distances between each cluster representative point and the data belonging to that cluster, is [(9)], so that eventually the classification into each cluster will not change.

【Options for (iii)】

a	monotonically decreasing	b	monotonically increasing	c	generative model	d	unsupervised learning
e	supervised learning	f	reinforcement learning	g	k-means method	h	EM algorithm

(iv) Q-learning is a reinforcement learning technique that estimates the value of [(10)] as a Q value. In the updating equation in Q learning, the Q value is updated to the value of the product of [(11)] and [(12)] plus the current Q value. The [(11)] derives from the non-convergence of the Q values during learning so Q-learning is learning to make the value of [(11)] closer to 0. The [(12)] represents the degree of reflection of the [(11)] in the Q value and the momentum of approaching the equilibrium state.

【Options for (iv)】

a	least-squares error	b	Temporal Difference error	c	state-value function	d	optimal action-value function
e	Bellman equation	f	reward	g	learning rate	h	discount rate

(v) Given a premise by a formula X and a conclusion by a formula Y, consider proving $Z := (X \rightarrow Y)$. That is, Z proves to be [(13)]. Then, $\neg Z \equiv$ [(14)] is satisfied, and Z proves to be [(13)] by repeatedly applying the [(15)] to the clause set of $\neg Z$ and deriving an empty clause. Note that the [(15)] is to obtain $P \vee R$ from the two clauses $P \vee Q$ and $R \vee \neg Q$ for literal Q.

【Options for (v)】

a	$X \vee \neg Y$	b	$X \wedge \neg Y$	c	tautology	d	contradiction
e	$\neg X \vee Y$	f	resolution principle	g	unification	h	clause form

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 section consists of 4 pages. Answer all the questions below.

Question 1.

(1) By using the tone curve in Figure 1, perform a pixel-wise tone mapping. When the pixel values of the input image are distributed throughout the range ①, which description is most appropriate for the output image?

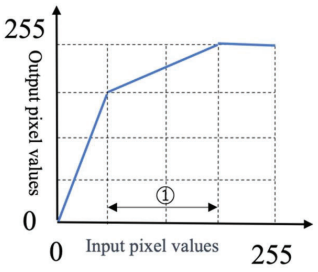

Figure 1

【Options】

(a). The intensity histogram of the output image is flattened.

(b). The blur of the input image is restored in the output image.

(c). The output image becomes brighter than the input image.

(d). The output image has higher contrast than the input image.

(e). The edges of the input image are enhanced in the output image.

(2) When a 3x3 pixel median filter is applied to the input image in Figure 2, what will be the output value corresponding to the pixels within the thick border in Figure 2?

144	121	135	124	125
53	107	226	137	129
18	134	128	107	27
16	122	140	135	138
107	111	116	116	237

Figure 2

【Options】

(a) 107 (b) 128 (c) 135 (d) 138 (e) 140

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* This section consists of 4 pages.

Question 2.

To transform the parallelogram shown in Figure 3 into a square with side length 1 as shown in Figure 4, which coordinates should be used? Let's denote the coordinates before the transformation as (x, y) and the coordinates after the transformation as (x', y').

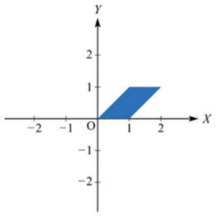

Figure 3

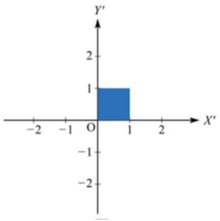

Figure 4

a) $\begin{cases} x' = x - 1 \\ y' = -y \end{cases}$ *b)* $\begin{cases} x' = x + y \\ y' = x - y \end{cases}$ *c)* $\begin{cases} x' = x - y \\ y' = y \end{cases}$ *d)* $\begin{cases} x' = x - 1 \\ y' = x + y \end{cases}$

Question 3.

In the image f (x, y), the density values at coordinates (1, 1), (1, 2), (1, 3), (2, 1), (2, 2), (2, 3), (3, 1), (3, 2), (3, 3) are $f(1,1) = 50$, $f(1,2) = 60$, $f(1,3) = 70$, $f(2,1) = 80$, $f(2,2) = 90$, $f(2,3) = 100$, $f(3,1) = 110$, $f(3,2) = 120$, $f(3,3) = 130$. Calculate the values of $f(1.3, 1.6)$ using the nearest neighbor and bilinear interpolation methods.

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* This section consists of 4 pages.

Question 4.

(1) A 2D Fourier transform was performed on the image shown in Figure 5. Which one of the following options in the answer group represents the resulting power spectrum? In the power spectrum, the center represents the DC component, and the higher values are represented by whiter areas.

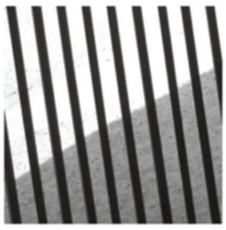
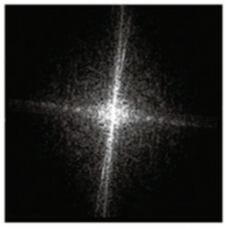
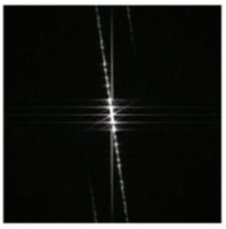
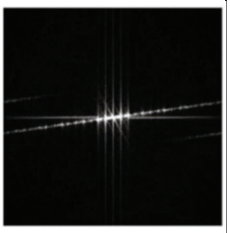


Figure 5

【Answer group】

				
a)	b)	c)	d)	e)

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* This section consists of 4 pages.

(2) Apply a 2D Fourier transform to the image in Figure 6 and obtain the power spectrum. Next, using the mask shown in Figure 7, preserve only the non-central part of this power spectrum. Which one of the following images in the answer group represents the resulting image obtained by inverse Fourier transforming the preserved power spectrum? Please note that the options provided represent the black rectangular waveframe surrounding the images and not the actual result of the inverse Fourier transform.

Figure 6

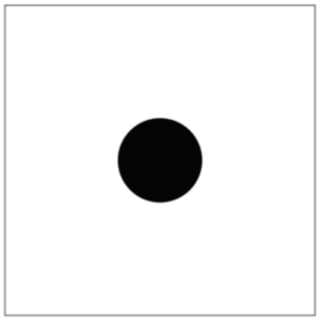

Figure 7

【Answer group】

a)

b)

c)

d)

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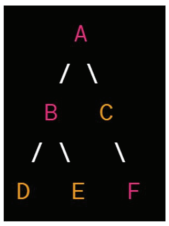
Human Information Science⑪ Artificial Intelligence

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

Question 1.

Consider the following graph:



Perform a depth-first search on this graph starting from node A, with priority given to the left side. Among the following seven steps, fill in the open list and the closed list at Step 4 and Step 7.

Step	Open List	Closed List
1	[A]	[]
2		
3		
4	(a)	(b)
5		
6		
7	(c)	(d)

Question 2.

A store sells only two types of laptops, X and Y. A certain ratio of both types is known to be defective. The probability that a laptop purchased at the same store is defective is 0.125 when the laptop is of type X. Which of the following choices is correct?

(a) The ratio of X sold in the same store is 0.8, the defective ratio of X is 0.4, and the defective ratio of Y is 0.7.
(b) The ratio of X sold in the same store is 0.6, the defective ratio of X is 0.4, and the defective ratio of Y is 0.7.
(c) The ratio of X sold in the same store is 0.4, the defective ratio of X is 0.4, and the defective ratio of Y is 0.7.
(d) The ratio of X sold in the same store is 0.2, the defective ratio of X is 0.4, and the defective ratio of Y is 0.7.
(e) The ratio of X sold in the same store is 0.1, the defective ratio of X is 0.4, and the defective ratio of Y is 0.7.

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* This section consists of 2 pages.

Question 3.

Answer the words or phrases suitable for the following blanks.

① In the K-means method, data are assigned to the [(a)] cluster, and then [(b)] is updated.

② The Bellman equation in reinforcement learning defines the state value of [(c)] with only the next reward and the value of [(d)]

③ In the steepest descent method (or gradient method), the parameters are modified by calculating [(e)] of the error function so that the error becomes [(f)]

February 2024 Admissions

AY2024 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.

1) Choose two questions from question ①~③ for Common Subjects.
2) Choose either the Computer Science section or the Human Information Science section for Specialized Subjects.
   ・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 ⑩or⑪.
   *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 Subjects ① Linear Algebra

Answer all the questions below with the derivation process.

Question 1. Find the point P that internally divides the line segment XY connecting points $\mathrm{X}(4,-1,3)$ and $\mathrm{Y}(2,0,-5)$ in the ratio $2:3$, and the point Q that externally divides it.

Question 2. When four points $\mathrm{A}(3,-2,5), \mathrm{B}(-3,-2,1), \mathrm{C}(0,2,-4)$, and $\mathrm{D}(1,1,0)$ are given, answer the following questions.

(1) Find the cross product $\overrightarrow{\mathrm{AB}} \times \overrightarrow{\mathrm{AC}}$.

(2) Find the real numbers a, b, c, and d in the equation $ax + by + cz + d = 0$ that represents the plane passing through three points A, B, and C.

(3) Calculate the area of triangle ABC.

(4) Calculate the volume of tetrahedron ABCD.

Question 3. When the matrices G and H are given, find the integer n $(0 < n < 30)$ that satisfies $G^n = H^n$.

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

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Common Subjects ② Probability and Statistics

Answer all of the following questions. Provide detailed explanations of all calculations and thought processes.

Question 1. Given the joint probability density function $P(x, y)$ of two continuous random variables X and Y as

$$P(x, y) = C \exp\left(-\frac{(x+y)^2}{2} - k\frac{(x-y)^2}{2}\right)$$

(with $k > 0$, $C > 0$), answer the following questions.

(1) Find C, and determine the marginal distributions $P(x) = \int_{-\infty}^{\infty} P(x, y)dy$ and $P(y) = \int_{-\infty}^{\infty} P(x, y)dx$.

You may use $\int_{-\infty}^{\infty} e^{-a(x-b)^2}dx = \sqrt{\frac{\pi}{a}}$.

(2) Find the conditional probability density function $P_Y(y|X = x)$.

(3) Show the condition under which two general random variables Z_1 and Z_2 are independent using the conditional probability density function $P_{Z_2}(z_2|Z_1 = z_1)$.

(4) Determine the condition for k where the random variables X and Y are independent.

Question 2. For a Poisson distribution with parameter λ,

$$P(X = k) = \frac{\lambda^k e^{-\lambda}}{k!},$$

answer the following questions.

(1) Find the mean of the Poisson distribution.

(2) Find the variance of the Poisson distribution.

(3) Assume that a population following a Poisson distribution yields 10 independent samples $X_1, X_2, \cdots, X_{10}$. Express the log-likelihood function $L(\lambda)$ using $X_1, X_2, \cdots, X_{10}$.

(4) Find the value of λ that maximizes the log-likelihood function $L(\lambda)$ from (3).

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Common Subjects ③ Data Structure and Algorithm

Answer all the questions below.

Question 1. Fig. 1 shows an example of a connected directed graph $G = (V, E)$, where the circle indicates vertices and the number in the circle indicates its vertex number. Fig. 2 shows the pseudocode for the breadth first search (BFS) algorithm from a vertex $s \in V$ of a connected directed graph G. Assume any graph G' with $|V| = n$ and $|E| = m$. Answer the following questions (1)-(5).

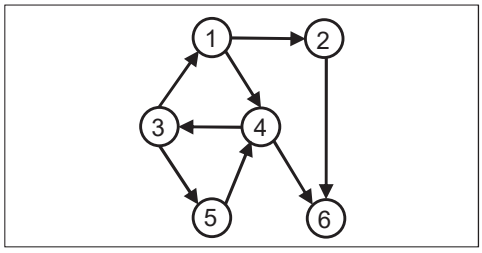

Fig. 1: Example of directed graph $\boldsymbol{G}$.

```
1: function BFS(G, s):
2:     create an empty queue Q
3:     mark vertex s as visited
4:     ENQUEUE(Q, s)
5:     while Q is not empty
6:         u ← DEQUEUE(Q)
7:         for each adj vertex v of vertex u do
8:             if v is not visited them
9:                 mark vertex v as visited
10:                ENQUEUE(Q, v)
```

Fig. 2: Pseudocode of a Breadth First Search (BFS).

(1) When graph G' is represented using an adjacency matrix, answer the time complexity required to determine whether two vertices are adjacent, in order notation.
(2) When graph G' is represented using an adjacency list, answer the space complexity in order notation.
(3) Given a graph G in Fig. 1 and a vertex 1 as s in the algorithm of BFS in Fig. 2, shows the order of all visited vertices, starting from 1. Order the adjacent vertices of each vertex according to increasing vertex number.
(4) Given any graph G' in the algorithm of BFS in Fig. 2, answer space complexity of the queue Q in order notation.
(5) Briefly answer what needs to be changed in the processing regarding the queue when the pseudocode in Fig. 2 is changed to the depth first search (DFS) algorithm.

Question 2. Answer the most appropriate word or equation in the following blanks [(1)] to [(10)] regarding sort algorithms.

When sorting data consisting of n elements, if the range of numbers to be sorted is known in advance, fast algorithms with a time complexity of $O(n)$, such as a [(1)], can be used. On the other hand, "selection sort", "merge sort", and "quick sort" are more general sorting algorithms. When sorting in ascending order, the selection sort repeats the processes of selecting the element with [(2)] from the unsorted part of the data and swapping it with the first element of the unsorted part, and has average and worst-case time complexities of O([(4)]). Merge sort works by recursively dividing data into two parts, and merging the divided element while sorting each other sorting, and has an average-case time complexity of O([(5)]) and a worst-case time complexity of O([(6)]). Quick sort recursively repeats the process of dividing the data based on a criterion called [(7)], and has an average-case time complexity of O([(8)]) and a worst-case time complexity of O([(9)]). When sorting algorithms are distinguished as stable and unstable, merge sort is a [(10)] sort.

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 Science ④ Computer Architecture

Answer all the questions below.

In the following, "ADD $1, $2, $3" means an instruction that adds the values stored in Register 2 and Register 3, and stores the result of the addition into Register 1.

Question 1.

Consider the execution of the following four instruction sequences: i1, i2, i3, and i4.

i1: ADD $1, $2, $3
i2: ADD $4, $1, $5
i3: ADD $6, $3, $5
i4: ADD $7, $5, $6

Explain which instructions are executed during each clock cycle for both out-of-order execution and in-order execution of the four instructions above in a CPU capable of executing two ADD instructions simultaneously in one clock cycle.

Question 2.

Consider the execution of the following five instruction sequences: i1, i2, i3, i4, and i5, in a CPU capable of executing two ADD instructions simultaneously in one clock cycle. If two ADD instructions can be executed in one clock cycle, all executions should be completed within three clock cycles. However, we cannot complete the following five instruction sequences in three clock cycles. Explain the reason.

i1: ADD $1, $9, $3
i2: ADD $3, $1, $2
i3: ADD $5, $3, $7
i4: ADD $3, $9, $8
i5: ADD $4, $3, $2

Question 3.

As a method to resolve the situation in Question 2, there is a technique called "register renaming." Explain how register renaming allows for the parallel execution of the five instructions in Question 2.

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Computer Science ⑤ Operating System

When a program is started, it is managed by the OS as a process. Moreover, it is executed with transitions of some states depending on the program code and in relation to other processes. Answer all the questions below about the state transitions of this process:

Question 1.
Explain what kind of states a process can have.

Question 2.
Explain under what circumstances the state of process transitions occur using a state transition diagram.

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Computer Science ⑥ Software Engineering

Answer all the questions below.

Question 1.
Software development processes include the waterfall model and evolutionary prototyping. Describe the differences between them from the perspective of managing the risk of not being able to define requirements specifications completely at the initial development phase.

Question 2.
Explain the module strength (or cohesion), which is a criterion for measuring module independence.

Question 3.
Describe why a "stub" is needed in top-down integration testing.

Question 4.
Describe the advantages of introducing version control as a software development practice.

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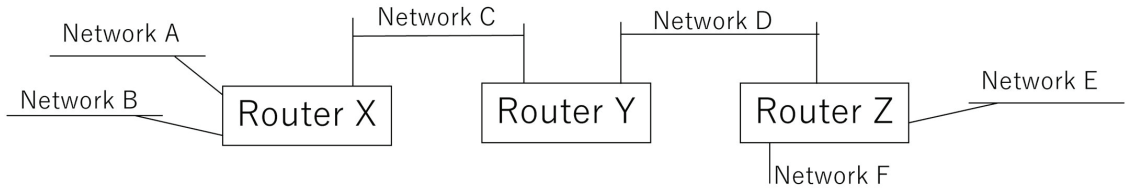
Computer Science ⑦ Computer Networks

Answer all the questions below.

Question 1.

The routing tables for routers X, Y, and Z in the network below were constructed using the distance vector algorithm. Please complete the three routing tables below. Write the answers in the answer sheet.



Router X

Destination	Next	Distance
A	X	0
B	X	0
(1)	(2)	0
(3)	(4)	1
E	(5)	2
(6)	Y	(7)

Router Y

Destination	Next	Distance
C	Y	0
D	Y	0
(8)	X	1
B	(9)	(10)
E	(11)	(12)
F	(13)	(14)

Router Z

Destination	Next	Distance
D	Z	0
E	Z	0
F	Z	0
(15)	(16)	1
(17)	(18)	2
B	(19)	(20)

Question 2.

An image, characterized by a resolution of 5120×2880 pixels (5K) and employing true color (utilizing 3 Bytes per pixel for color information), is subjected to transmission over a 2.5 Gb/s Ethernet connection. What is the duration required for the transmission of the uncompressed image?

Question 3.

For the descriptions regarding computer networks, write T if it is true or F if it is false in the answer sheet.

(1) Ethernet is a LAN, so it is placed in the second layer of the OSI reference model.
(2) UDP provides connectionless service and delivers packets quickly. In case of packet loss, UDP does not provide retransmission.
(3) DNS performs the translation of a hostname to its corresponding MAC address.
(4) UDP is preferred over TCP for real-time transmission of voice over IP networks.
(5) Framing is an essential requirement in frequency division multiplexing.
(6) Circuit switching networks require signaling and control for establishing circuits.
(7) One of the ways to reduce transmission delay is to use a higher-speed transmission system.
(8) With longer frames or shorter propagation time, higher utilization (efficiency) can be achieved in Ethernet LANs.
(9) HTTP (Hyper Text Transfer Protocol) operates on top of UDP.
(10) In a bus topology, each station on the network is interconnected with two other stations, forming a loop or ring.

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Computer Science ⑧ Databases

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

Question 1.

Relation "sales" in the first normal form is as shown below, and the primary key is {slip_num, product_code}.

sales (slip_num, store_ID, store_name, store_address, sales_date, product_code, product_name, unit_price, quantity, subtotal)

In this relationship, the following partial functional dependencies exist.

{slip_num}→{store_ID, store_name, store_address, sales_date}

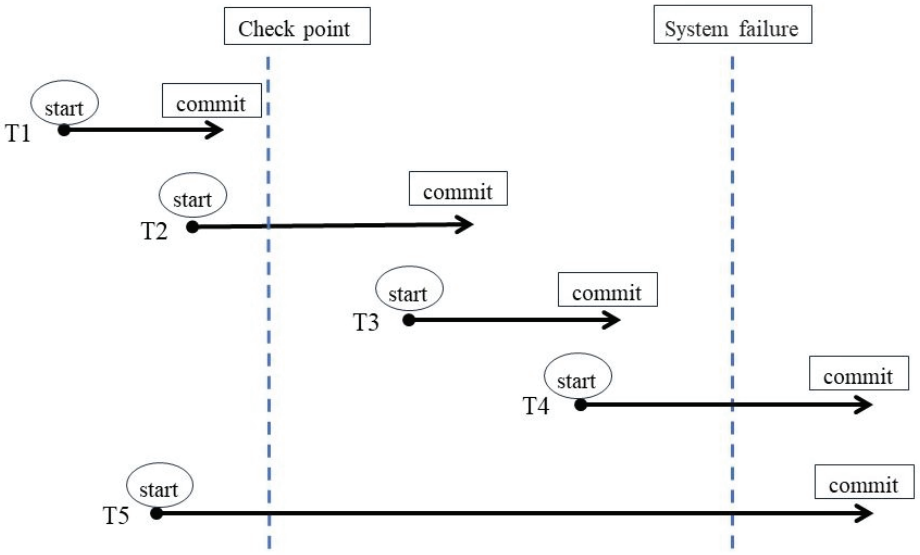
{product_code}→{product_name, unit_price}

Show the normalization results of this relation into second normal form and underline key attributes.

Question 2.

Describe the definitions that apply to [A] and [B] in the following description about database failure recovery, and answer the questions below (1) and (2).

Database failure recovery is performed using checkpoints and logs. The DBMS can cancel operations on transactions that could not be committed due to a failure. This process of using logs to return to the state before the start of the transaction is called [A]. Transactions committed from the checkpoint to the time of failure are reproduced by reflecting the processing written in the log in the data. This kind of processing is called [B].



(1) List all transactions that require processing A in the diagram above.

(2) List all transactions that require processing B in the diagram above.

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* This section consists of 2 pages.

Question 3.

Write the following queries (1) and (2) in SQL regarding the following relational tables 'Student' and 'Student club'.

Relation: Student

stu_NO	name	sex	GPA	dep_num
1001	Hiromi Yasuda	women	3.3	3
1002	Katsumi Kimura	men	4.1	1
1003	Shinji Sakurai	men	4.3	2
1004	Takashi Irie	men	3.2	3
1005	Shinichi Tamura	men	3.7	1
1006	Noriko Ichikawa	women	3.4	2

Relation: Student club

stu_NO	student_club_name	joining_date
1001	tea ceremony	2023-4-1
1003	football	2022-4-1
1005	golf	2023-10-1
1006	table tennis	2022-5-1

(1) Output the department number and highest GPA for each department in order of department number.

(2) Output the names of students who have belonged to student clubs since April 2023 and the names of the student club they belong to.

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Computer Science ⑨ 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 the box with the same number.

(i) All comments are classified as either positive or negative content, and we consider using a [(1)] to determine whether a given comment is positive or negative. The [(1)] is a classifier based on a [(2)] . It assumes that there is no interdependence or correlation in the generation of words, and classifies documents based on Bayes' theorem. The occurrence probabilities of the three words in each type of content are shown in Table 1, and the occurrence of each word is assumed to be independent of each other. When positive content is posted with probability 0.6, the probability that a comment containing "recommend" and "performance" and not containing "return" is positive is [(3)] .

Table 1: The occurrence probabilities of the three words

	"recommend"	"return"	"performance"
Positive content	0.70	0.10	0.50
Negative content	0.30	0.25	0.40

【Options for (i)】

a	SVM	b	naive Bayes filter	c	discriminative model	d	probabilistic generative model
e	n-gram model	f	0.189	g	0.652	h	0.840

(ii) A game in which the sum of the players' payoffs is zero is called a [(4)] . Table 2 shows a payoff matrix for that game, and the values in the table are the payoffs of Player 1. A strategy where a player assumes that they will only receive the minimum possible payoff for their actions and, among these, choose the action that maximizes their own payoff is called [(5)] . If Player 1 follows this strategy, Player 1 chooses action [(6)] in the game shown in Table 2.

Table 2 : Payoff matrix

		Player 2		
		b_1	b_2	b_3
Player 1	a_1	4	3	3
	a_2	1	5	2
	a_3	3	2	4

【Options for (ii)】

a	minimax strategy	b	maximin strategy	c	extensive-form game	d	Nash game
e	a_1	f	a_2	g	a_3	h	zero-sum game

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* This question consists of 2 pages.

(iii) Let s_t be the state at time t, a_t be the action taken at time t, o_t be the result of the observation at time t, and $F_t(s_t)$ be the probability that the state is s_t at time t. In this case, the Bayesian filter, an algorithm for self-location estimation, performs the following calculation at each time t. Fill in the blanks in the formula.

1. For all s_t, calculate $G_t(s_t) \leftarrow$ [(7)] $\sum_{s_{t-1}}$ [(8)] $F_{t-1}(s_{t-1})$, and
2. For all s_t, calculate $F_t(s_t) \leftarrow G_t(s_t) / \sum_s G_t(s)$,

Also, the process performed in 2. is [(9)] .

【Options for (iii)】

a	$P(s_t)$	b	$P(a_t \mid s_t)$	c	$P(o_t \mid s_t)$	d	$P(s_t \mid a_{t-1})$
e	$P(s_t \mid s_{t-1}, a_{t-1})$	f	Generalization	g	Resampling	h	Normalization

(iv) [(10)] are widely used neural networks in image recognition. In [(10)] , the pooling layer plays a role in reducing the dimensions of the input vector. Additionally, [(11)] are neural networks that can learn to predict output values for sequential data arranged in time by having internal variables that retain contextual information. In the learning process of [(11)] , there is a method called [(12)] , which is an extension of the backpropagation method that unfolds in the time direction.

【Options for (iv)】

a	Ward's method	b	kernel method	c	BPTT method	d	recurrent neural networks
e	k-means clustering	f	BERT	g	simple perceptron	h	convolutional neural networks

(v) In natural language processing, the division of sentences into their smallest grammatical units and the estimation of parts of speech is called [(13)] , and the process of analyzing grammatical structures according to the grammar of a given language is called [(14)] . In [(14)] based on context-free grammar, assuming phrase structure grammar, the results of the analysis are represented in a structure known as a [(15)] .

【Options for (v)】

a	morphological analysis	b	syntactic analysis	c	semantic analysis	d	context analysis
e	ontology	f	syntactic tree	g	word lattice	h	semantic network

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 Science ⑩ Image Processing

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

Question 1.

40	**60**
50	**70**

is a 2 by 2 image, where the coordinates of the 4 pixels are (0,0),(1,0),(0,1),(1,1) and the pixel values are I(0,0)=40, I(1,0)=60, I(0,1)=50, I(1,1)=70. Determine the subpixel value I(0.3,0.6) by bilinear interpolation.

Question 2.

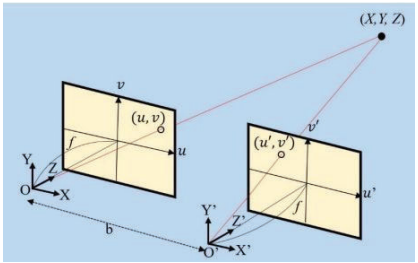
$F(x) = A(-x)\exp(-\frac{x^2}{2})$ is the first derivative of a Gaussian function, where A is a positive integer. We are to design a digital filter representing this function F(x), where each point has a filter value of 8 bits ranging from -128 to 127.

(1) Determine the coordinate x1 for the point which has the maximal value of F.
(2) Determine the coordinate x2 for the point which has the minimal value of F.
(3) Determine A as an integer.
(4) Determine U as an integer where (2U+1) is the filter size.

For your convenience, exp(-1/2)≒0.6, exp(-2)≒0.135 , exp(-9/2)≒0.0111, exp(-8)≒0.0003.

Question 3.

The figure shows a parallel stereo, where the distance between the two cameras is 100mm, and the point on the left image (500 pixels,100 pixels) corresponds to the point on the right image (300 pixels,100 pixels). 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) is on the Z axis, and two cameras have exactly the same intrinsic parameters and f =1000 pixels.



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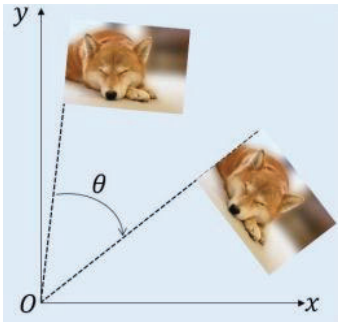
* This section consists of 2 pages.

Question 4.

After rotating the image clockwise by 60 degrees as shown in the figure, it is further translated by 30 in horizontal direction and -10 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 Science ⑪ Artificial Intelligence

Answer all the questions below.

(1) There are seven data points in X as follows. Cluster them using the k-means method with k=3.

$$X = \{(0,0), (0,1), (0,2), (3,0), (6,0), (6,1), (6,2)\}$$

With the initial set of centroids C as

$$C = \{(0,4), (3,0), (6,4)\}$$

perform the k-means clustering until convergence and show the entire process. Regarding the process, show the changes in the coordinates of the centroids at each step, and the allocation of each data point to the clusters.

(2) Find the Skolem normal form of the following predicate logic formula and represent it in clause set form.

$$\forall x \exists y[P(x) \rightarrow Q(x,y)] \wedge \neg(\forall x \exists y[P(x) \wedge \forall z\, R(z)])$$

(3)

(3-1) Explain the difference between Nash equilibrium and dominant strategy equilibrium in game theory.

(3-2) What is a Gaussian Mixture Model (GMM)? Explain.

(3-3) What is an n-gram model in natural language processing? Explain it with an example.

(3-4) Explain the differences between supervised learning, reinforcement learning, and unsupervised learning.