Summer Examination, 2008

Department of Creative Informatics
Graduate School of Information Science and Technology
The University of Tokyo

Information Science and Technology

Instructions

1. Do not open this brochure until the signal to begin is given.
2. Write your examinee ID below on this cover.
3. Answer three out of the four problems in Japanese or English.
4. Three answer sheets are given. Use a separate sheet for each problem. You may continue to write your answer on the back of the answer sheet if you cannot conclude on the front.
5. Write down the examinee ID and the problem ID inside the top blanks of each sheet.
6. The answer is considered invalid if any unrelated marks, codes or phrases are included.
7. Do not take out the sheets and this brochure from this room.

Examinee ID _____

Problem 1

Let N be the number of divisors of a positive integer J. Let us compute the smallest J for a given N. Note that J and 1 are included among the divisors of J.

(1) Calculate the smallest J each for $N = 5$ and $N = 8$.

(2) Let J be prime factorized as

$$J = \prod_{i=0}^{k-1} p_i^{a_i}$$

where p_is are mutually different prime numbers and a_is are positive integers for $0 \leq i < k$. Describe N in a mathematical formula.

(3) When N is odd, what kind of number is J ?

(4) Based on (2), describe the outline of a method to compute the smallest J given N. Moreover, describe ways to decrease computational complexity.

(5) Calculate the smallest J for N=24.

Problem 2

Synchronization operation among processing elements in a multi-computer is essential to realize mutual exclusion, producer-consumer synchronization. Answer the following questions on realization of synchronization in a multi-computer:

(1) When the multi-computer has a shared memory, describe a method to realize mutual exclusion, then write a pseudo-program to implement the operation.

(2) Atomic operations of memory-read and memory-write are necessary to implement synchronization for mutual exclusion (*1). "Test and set" or "compare and swap" realizes an atomic operation necessary to implement the synchronization. Describe the reason why an atomic operation of memory-read and memory-write is necessary to implement the synchronization (*2).

(3) In a distributed-memory multi-computer, synchronization can be realized by message communication. Show that synchronization functions realized by message communication and semaphore are equivalent.

(4) Synchronization methods used in Q1 to Q3 can perform a constant number of synchronization, e.g. number of mutual exclusion operations in a unit time. It is not scalable to the number of processors in the system. Describe the method to realize scalable synchronization where the number of synchronization in a unit time is proportional to the number of processors in the system.

(*1) Implementation of synchronization without atomic operations exists. However, this method is not used for practical purposes.

(*2) If synchronization method to be considered does not use atomic operation, show the outline of synchronization method instead of necessity of atomic operation.

Problem 3

Consider a method to find equations of two straight boundary lines of the two-colored regions like Fig. 1. Suppose the points in Fig. 2 are derived through processing the image of Fig. 1 and answer the following questions.

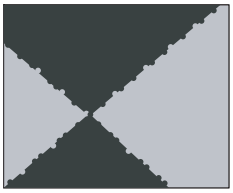

Fig. 1

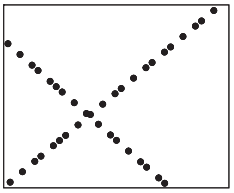

Fig. 2

(1) The line L_0 that passes the point (x_0, y_0) as in Fig. 3 is described as

$$y = a_0 x + b_0.$$

The point $\mathrm{P}_0(a_0, b_0)$ of the a-b parameter coordinates (Fig. 4) shows the line L_0. Explain what the parameters of a_0, b_0 mean in the x-y coordinates.

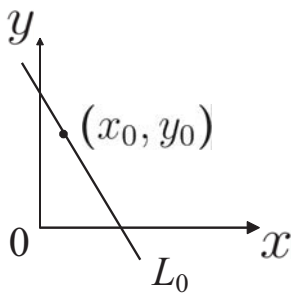

Fig. 3

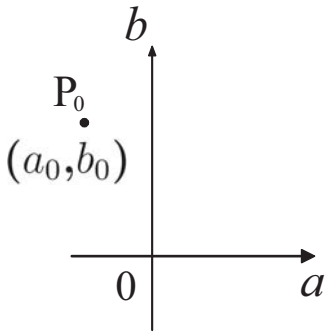

Fig. 4

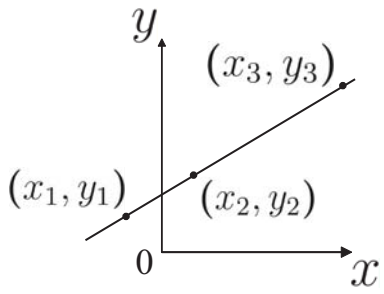

Fig. 5

(2) Rotate the line L_0 in Fig. 3 at the point (x_0, y_0). Illustrate the trajectory of the point P_0 in the a-b coordinates.

(3) Consider the three points (x_i, y_i), $1 \leq i \leq 3$ on a line as in Fig. 5. Let L_i be a line that passes (x_i, y_i), $1 \leq i \leq 3$. Rotate each line L_i at (x_i, y_i). Illustrate the corresponding trajectories of the point P_i in the a-b coordinates.

(4) Considering the methods described above, explain how to get the equations of the two straight boundary lines from the points of Fig. 2.

Problem 4

Select four items out of the following eight items regarding information systems, and explain each item in approximately 4〜8 lines, using examples or images if necessary.

(1) Divide and conquer algorithm

(2) B-tree

(3) Nyquist frequency

(4) Impulse response, step response, and their relation

(5) Vector quantization

(6) Out-of-order execution

(7) Regular grammar and regular language (Examples are mandatory.)

(8) CGI (Common Gateway Interface) in Web system