2016 Summer Entrance Examination

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Creative Informatics

Instructions

1. Do not open this brochure until the signal to begin is given.
2. Write your examinee ID number below on this cover page.
3. Answer <u>three problems out of the four</u>.
4. Three answer sheets are given. Use a separate sheet of paper for each problem. You may write on the back of the sheet.
5. Write down your examinee ID number and the problem number inside the top blanks of each sheet.
6. Do not remove the answer sheets or this brochure from this room.

Examinee ID ______________________________

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Problem 1

Using electronic components, let us build a single digit counter in base-k, where k is an integer equal to or greater than 2. Inputs for the counter are a clock signal (signal CLK) and an enable signal (signal EN), and an output is a counter value c (Fig. 1). The signals CLK and EN are binary with the values of H and L. The signal CLK is periodic as Fig. 2, and let the rising edge denote the transition from L to H of the signal CLK. The counter value is $0 \leq c \leq k-1$, which is initialized to $c = 0$ for starting.

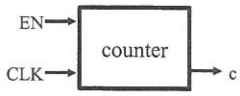

Fig. 1

Fig. 2

Consider a single digit binary counter as an example. Let c and c' denote the counter values before and after the rising edge of the signal CLK, respectively. On the rising edge of the signal CLK,

$$\begin{cases} c' = (c+1)\ mod\ 2, \text{ if the signal EN is H,} \\ c' = c, \text{ if the signal EN is L,} \end{cases}$$

where the operator *mod* returns the positive remainder. We show an example of the state diagram in Fig. 3 and the state transition table in Table 1 of this binary counter. Here, S0 and S1 are states with the counter values 0 and 1, respectively.

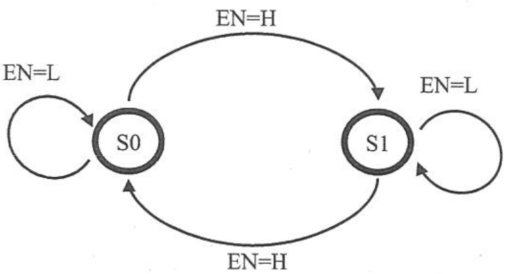

Fig. 3

Table 1

before		Input	after	
state	c	EN	state	c'
S0	0	L	S0	0
S0	0	H	S1	1
S1	1	L	S1	1
S1	1	H	S0	0

Answer the following questions.

(1) Show a state diagram and a state transition table of a single digit ternary counter such that on the rising edge of the signal CLK,

$$\begin{cases} c' = (c+1)\ mod\ 3, \text{ if the signal EN is H.} \\ c' = c, \text{ if the signal EN is L.} \end{cases}$$

For the transition diagram and the transition table, you may use a different format from the example.

(2) Let us extend the counter in Question (1) to an up-down counter. Use an up-down signal (signal UD) as an input instead of the signal EN. Show a state diagram and a state transition table of a single digit ternary counter such that, on the rising edge of the signal CLK,

$$\begin{cases} c' = (c+1)\ mod\ 3, \text{ if the signal UD is H.} \\ c' = (c-1)\ mod\ 3, \text{ if the signal UD is L.} \end{cases}$$

For the transition diagram and the transition table, you may use a different format from the example.

Let us assemble the following components to realize the counters described in Question (1) and Question (2). The inputs and the outputs of the components A, B, C, D and E are shown in Fig. 4. The relationships between input and output values are shown in Table 2, 3, 4 , 5 and 6. The component E sets the value of I just before the rising edge of the signal CLK to the output O after the rising edge. In general, the components A, B, C, D and E are called NOT, AND, OR, XOR and D-flipflop, respectively.

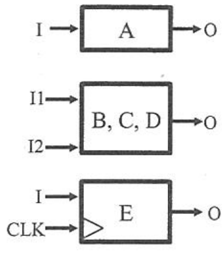

Fig.4

Table 2

A

I	O
L	H
H	L

Table 3

B

I1	I2	O
L	L	L
H	L	L
L	H	L
H	H	H

Table 4

C

I1	I2	O
L	L	L
H	L	H
L	H	H
H	H	H

Table 5

D

I1	I2	O
L	L	L
H	L	H
L	H	H
H	H	L

Table 6

E

before	after
I	O
L	L
H	H

The signal EN and the counter value c change on the rising edge of the signal CLK. First, we show an example of the single digit binary counter. Since this binary counter value c is either 0 or 1, we use a binary signal C_0 to represent c, where C_0 is set to L when $c = 0$, and set to H when $c = 1$. Let C_0 denote this before the rising edge of the signal CLK and C_0' that after the rising edge, respectively. The relationship of the signal C_0, EN and C_0' is described in Table 7, thus, this single digit binary counter is, for example, realized as a logic circuit diagram in Fig. 5.

Table 7

C_0	EN	C_0'
L	L	L
H	L	H
L	H	H
H	H	L

Answer the following questions. Suppose you have sufficiently many components and you do not need to use all kinds of components.

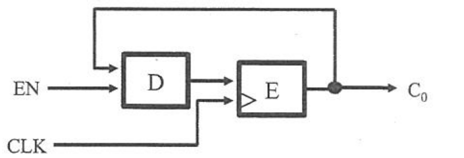

Fig. 5

(3) Draw a circuit diagram obtained by assembling the components to realize the single digit ternary counter described in Question (1). Use two bits to represent the counter value c. You may draw an ordinary logic circuit diagram.

(4) Draw a circuit diagram obtained by assembling the components to realize the single digit up-down ternary counter described in Question (2). Use two bits to represent the counter value c. You may draw an ordinary logic circuit diagram.

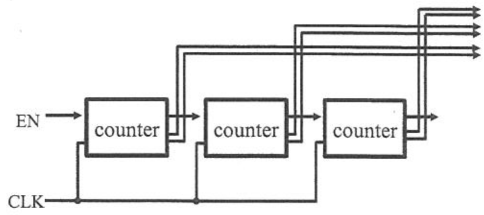

Fig. 6

(5) Let us combine single digit ternary counters to realize a three digits ternary counter in Fig. 6. Extend the single digit ternary counter described in Question (3) by adding a new output signal to realize a new single digit ternary counter which is a component of the three digit ternary counter, and draw a circuit diagram of this single digit ternary counter. You may draw an ordinary logic circuit diagram.

Problem 2

Consider a package delivery network, that is composed of nodes and edges, and the delivery route is calculated by the algorithm described below.

The route calculation algorithm, P :

Every node sends a routing table that consists of row vectors {Destination node, Number of hops to reach the destination node, Neighbor node where the packet is transferred} to all the neighbor node(s) connected by edge(s) every one minute. Then, the node recalculates its table, using the received routing table(s) from the neighbor node(s). Here, Fig. 1 shows an example of a routing table of Node 1 at some point of time. In the figure, the number of hops, h(i,j), represents the minimum number of hops so as to reach Node j from Node i, and is calculated by the following expression.

$h(i,j) \; = \; \min\{h(i,k) + h(k,j)\}, \; h(i,i)=0, \; h(i,k)=1$ for all neighbor Node k of Node i

Here, when there are multiple routes having the same number of hops, choose the route through the neighbor node with smaller node number. And, the initial state of the routing table at every node has only the vector whose destination is itself.

Destination node	Number of hops to reach the destination node	Neighbor node, where the packet is transferred
1	$h(1,1) = 0$	-
2	$h(1,2) = 3$	3
3	$h(1,3) = 1$	3
⋮	⋮	⋮
9	$h(1,9) = 6$	2

Fig.1

(1) Regarding the package delivery network shown in Fig. 2, show the time until the routing tables are converged. Also, show the routing table at Node 6 every one minute until the routing table is converged. Here, a number shown in a circle represents its node number. An edge connecting nodes is shown by a line with Li (i is an integer).

(2) Using the routing table information of the nodes in the system, a tree, that represents the route of packages from Node 6 as a root node to all the other nodes (1, 2, 3, 4 and 5), can be generated. Draw this tree.

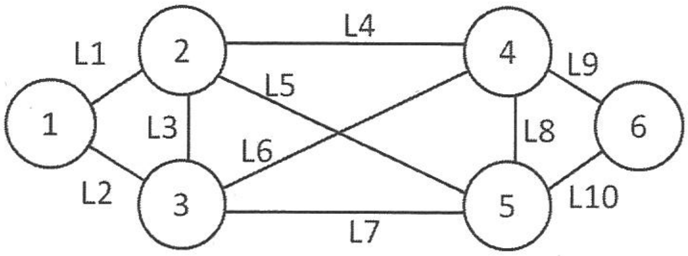

Fig.2

Regarding the package delivery network shown in Fig.2, we consider a digital communication network, where any size of package consisting of digital bits (called a packet, below) is delivered. Here, packets are transmitted only from Node 6 to Node 2. The edges L5 and L6 are of satellite link, whose delay is 500[ms] and bandwidth is 1[Mbps], the edges L4 and L7 are of wide-area land cables, whose delay is 50[ms] and bandwidth is 100[Mbps] and the rest of the edges are of local network cables, whose delay is 1[ms] and bandwidth is 1[Gbps],

(3) Consider a case where a size of eight megabit file is transferred from Node 6 to Node 2, while the file is divided into the same size of 1,000 packets, whose size is eight kilobit. Here, Node 6 sends the i-th ($1 \leqq i \leqq 1{,}000$) packet (S_i), Node 2 receives the packet S_i and sends a packet R_i indicating the reception of packet S_i to Node 6, Node 6 receives the packet R_i, then Node 6 sends the next packet (S_{i+1}) to Node 2. Show the file transmission time T, from the beginning of packet transmission by Node 6 until the completion of packet reception by Node 2. Here, we can ignore the delay after the completion of packet reception until the start of packet transmission at every node and the transmission time for the additionally attached data, such as a label informing the destination node. And, there is no packet loss nor corruption during the packet delivery.

(4) By the improvement of the packet transmission algorithm, described in Question (3), we can decrease the file transmission time T from Node 6 to Node 2. Describe a concrete method to decrease T.

(5) With an introduction of some improvement, such as changing the element in the routing table exchanged among nodes or changing the route calculation algorithm, into the route calculation algorithm P, we can decrease the file transmission time T from Node 6 to Node 2. Describe two concrete methods to decrease T, while showing how the packet delivery path(s) will change.

Problem 3

When synthesizing photorealistic images in computer graphics, lighting calculation is often done by integration based on geometric optics. Suppose that we define incoming radiance at a point on a plane from the angle (θ, ϕ) (see Fig. 1) as $L(\theta, \phi)$. Irradiance I at this point is known to be defined as

$$I = \int_0^{2\pi} \int_0^{\frac{\pi}{2}} L(\theta, \phi) \cos\theta \sin\theta \, d\theta d\phi.$$

Answer the following questions.

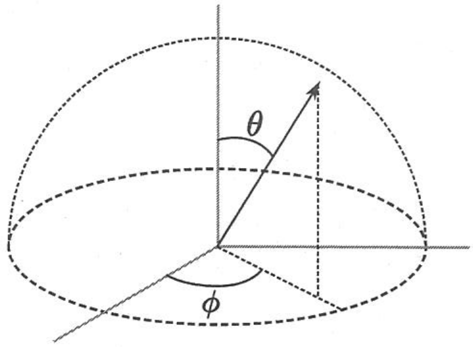

Fig. 1.

(1) Consider the situation where the distribution of radiance L is independent of θ. Show that irradiance I can be expressed as the following one dimensional definite integral:

$$I = \frac{1}{2} \int_0^{2\pi} L(\phi) d\phi.$$

We consider this situation in the following all questions.

(2) Suppose that we have $N+1$ values which are defined as $\phi_i = 2\pi(i/N)$ $(i = 0, \ldots, N)$. Fig. 2 shows that the area of the rectangle defined within the interval $[\phi_i, \phi_{i+1}]$ is given by $L(\phi_i)(\phi_{i+1} - \phi_i)$. Use this fact and write down an equation which approximates the irradiance I via the summation sign Σ. This method is commonly called the rectangle method.

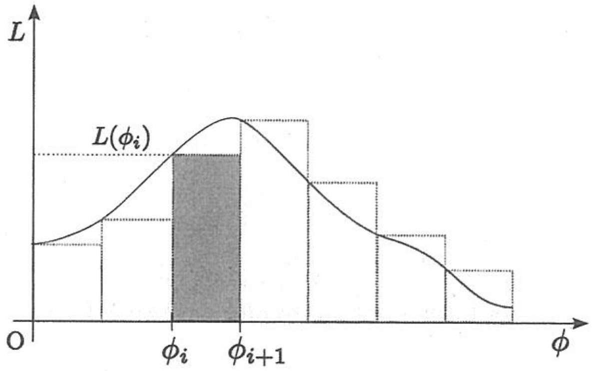

Fig. 2.

(3) In general, given a random variable ϕ which is distributed according to the probability density function $p(\phi)$ defined within $[0, 2\pi]$ (suppose that $p(\phi) > 0$), the expected value $\mathrm{E}[f(\phi)]$ of a scalar function $f(\phi)$ is defined as

$$\mathrm{E}[f(\phi)] = \int_0^{2\pi} f(\phi)\, p(\phi) d\phi.$$

Suppose that ϕ_i are N instances of the random variable generated according to $p(\phi)$ ($\phi_i \sim p(\phi), i = 1, \dots, N$). An approximation of the above expected value $\mathrm{E}[f(\phi)]$ is given by

$$\mathrm{E}[f(\phi)] \cong \frac{1}{N} \sum_{i=1}^{N} f(\phi_i).$$

Use this fact and write down an equation which approximates the irradiance I via the summation sign Σ. This method is commonly called Monte Carlo integration.

(4) Consider the error of the rectangle method and the expected error of Monte Carlo integration. Explain what kind of integrand $L(\phi)$ will result in zero error by each method (assuming $L(\phi) > 0$). Explain them based on your answers for Question (2) and Question (3). Exclude the trivial case for the rectangle method where $L(\phi)$ is a staircase function as shown in Fig. 2.

(5) You implemented the rectangle method or Monte Carlo integration using 32 bits floating point numbers. After N exceeded a certain large number, the result started decreasing toward zero. Explain one possible cause of this phenomenon. Assume that N is always accurately counted.

Problem 4

Select <u>four items</u> out of the following eight items concerning information systems, and explain each item in approximately four to eight lines of text. If necessary, use examples or figures.

(1) Kinematics and inverse kinematics

(2) Implementation method of force control (explain using a block diagram)

(3) Invariant features

(4) Backpropagation

(5) Autocorrelation function and power spectrum

(6) Synchronous and asynchronous circuits

(7) An example of network security protocol

(8) Real-time property

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