國立臺灣科技大學
115學年度碩士班招生

試題

系所組別：1500資訊工程系碩士班

科　　目：資訊工程概論

<<515001>>

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(總分為100分;所有試題務必於答案卷內頁依序作答)

考生注意：本試卷共計2大題，包含13子題(1~8, A~R)。
請在答案卷第一頁做表如下，將子題答案整理於該表中。否則，不予計分。

1		2		3		4	
5		6		7		8	

A		B		C		D	
E		F		G		H	
I		J		K		L	
M				N			
O				P			
Q				R			

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================ 試題開始 ================

Part I: Choice Questions

1. (5%) Select all statements that are true about AVL trees (named after inventors Adelson-Velsky and Landis).
   (a) The Balance Factor (BF) of a node is typically defined as the difference between the height of its left subtree and the height of its right subtree.
   (b) If the root node of a tree has a left subtree height of 3 and a right subtree height of 5, the tree is considered balanced according to AVL rules.
   (c) In an AVL tree with n nodes, the search time complexity in the worst-case scenario is $O(logn)$.
   (d) If a newly inserted node causes an LL (Left-Left) imbalance, a single right rotation is required to restore balance.
   (e) Assuming the height of a single root node is 1, an AVL tree with a height of 4 must contain at least 8 nodes to maintain its height.
   (f) After performing a single rotation on an AVL tree, the preorder traversal sequence is guaranteed to remain identical to the sequence before the rotation.

2. (5%) Select all statements that are true about a Binary Heap.
   (a) In a max heap, the value of the left child node must be greater than the value of the right child node.
   (b) A binary heap must satisfy the structural property of a complete binary tree.
   (c) In a binary heap containing n elements, the worst-case time complexity for inserting a new element is $O(nlogn)$.
   (d) The sequence $\{2,10,5,7,15,12\}$, when represented as an array, satisfies the definition of a min heap.
   (e) In a full binary heap of height h, if the height of a single root node is defined as 0, the total number of nodes is $2h$.
   (f) If a value smaller than all existing elements is inserted into a Max Heap, the best time complexity for that specific insertion is $O(1)$.

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3. (5%) Select all the correct statements.

(a) The conversion of the infix expression $(\boldsymbol{A}+\boldsymbol{B})\times \boldsymbol{C}$ into postfix expression results in $\times +\boldsymbol{ABC}$.

(b) Given the postfix expression $\mathbf{8\ 2\ 3} \times +$, the result of the evaluation is 14.

(c) Converting the infix expression $\boldsymbol{A}+\boldsymbol{B}\times(\boldsymbol{C}-\boldsymbol{D})\div \boldsymbol{E}$ into postfix expression (assuming standard left-associativity for operators of equal precedence) results in $\boldsymbol{ABCD}-\boldsymbol{E}\div\times+$.

(d) A stack follows the LIFO (Last-In-First-Out) access principle.

(e) In graph traversal algorithms, Depth-First Search (DFS) typically utilizes a stack, whereas Breadth-First Search (BFS) utilizes a queue.

(f) The worst-case time complexity for searching for a specific element within a stack containing n elements is $O(1)$.

4. (5%) Consider sorting an array of n elements using common sorting algorithms. Select ALL statements that are always correct.

(a) Any comparison-based sorting algorithm requires $\Omega(nlogn)$ comparisons in the worst case.

(b) Merge sort is stable and runs in $O(nlogn)$ time in the worst case.

(c) Heap sort is stable and runs in $O(nlogn)$ time in the worst case.

(d) Quick sort runs in $O(nlogn)$ time in the worst case if the pivot is chosen uniformly at random at each recursive call.

(e) Counting sort can run in $O(n+k)$ time, where k is the range of key values.

(f) Insertion sort runs in $\Theta(n+I)$ time, where I is the number of inversions in the input.

5. (5%) When performing DFS or BFS traversal on a cyclic graph, what could happen if you forget to use a visited array (or equivalent) to mark visited vertices?

(a) The traversal may fall into an infinite loop, continuing until a stack overflow (for DFS) or memory exhaustion occurs.

(b) The program crashes immediately.

(c) The algorithm will stop automatically, but the result will be inaccurate.

(d) The program can still perform correctly.

(e) There is no effect.

(f) The traversal will still terminate because DFS/BFS never visits the same vertex more than once by design.

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6. (5%) Let $f(n)$ and $g(n)$ be arbitrary functions $\mathbb{Z}^+ \to \mathbb{Z}^+$. Select ALL statements that are always correct.

(a) If $f(n) = \Theta(g(n))$, then $2^{f(n)} = \Theta(2^{g(n)})$.

(b) It is possible that $f(n) = O(g(n))$, but $g(n) \notin O(f(n))$.

(c) If $f(n) = O(g(n))$, then $f(n) + g(n) = \Theta(g(n))$.

(d) It is possible that $f(n) = \Theta(g(n))$, but $g(n) \notin \Theta(f(n))$.

(e) If $f(n) = O(g(n))$, then $2^{f(n)} = O(2^{g(n)})$.

(f) It is possible that $f(n) = o(g(n))$ and $g(n) = o(f(n))$.

7. (5%) Assume a B-tree and a B+ tree have the same order m, where m is the maximum number of children an internal node can have (i.e., each internal node has at most m children and thus at most $m-1$ keys; the root is allowed to have fewer children). Select ALL statements that are correct.

(a) In a B-tree, all actual records (data pointers) are stored only in the leaf nodes.

(b) In a B-tree, searching for a key always ends at a leaf node.

(c) For point lookups (exact-match search), a B-tree is always faster than a B+ tree because it can stop at an internal node.

(d) In a B+ tree, all actual records are stored only in the leaf nodes, and internal nodes store only keys (and child pointers).

(e) In a B+ tree, leaf nodes are typically linked together to support efficient range queries and sequential scans.

(f) Compared with a B-tree of the same order m, internal nodes in a B+ tree typically have a higher branching factor (i.e., more children), which often reduces tree height.

8. (5%) In an array-based implementation of a binary heap (assuming the root index starts from 1), if a node is at index i, what is the index of its left child?

(a) $3i + 1$

(b) $2i + 1$

(c) $i + 1$

(d) $i/2$

(e) $3i - 1$

(f) $2i$

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Part II: Fill-in-the-blank Questions

1. (5%) Consider an undirected simple graph consisting of 7 nodes. The degrees of these nodes are given by the set { 2, 2, 3, 4, 4, 5, x }. Based on the Handshaking Lemma, what is the minimum positive integer value that x can take? __(A)__

2. (5%) Consider the binary tree shown in the Fig. 1. Let a be the 5-th element of the inorder traversal, and let b be the 8-th element of the preorder traversal. The value of $a-b$ is __(B)__.

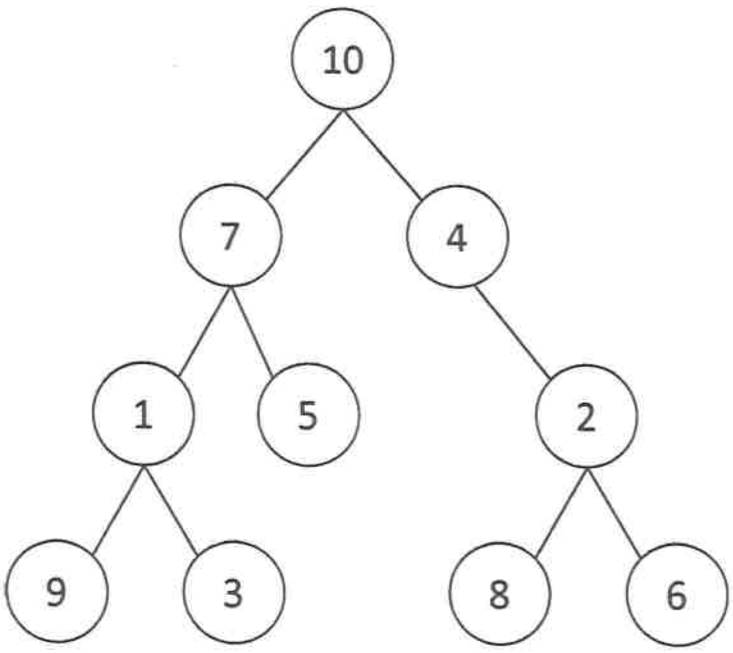

Fig. 1 A given binary tree

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3. (10%) Fig. 2 shows the single cycle processor design. Consider the following instruction:

Instruction: beq \$rs, \$rt, Label

Interpretation: $PC = \begin{cases} (PC + 4) + inst[0-15], & if(\$rs - \$rt == 0) \\ PC + 4, & otherwise \end{cases}$

What are the values of the following control signals generated by the control in Fig. 2. Put an 'x' if the value can be 0 or 1.

- (2%) RegDst = ___(C)___
- (2%) MemRead = ___(D)___ (0: inactivated, 1: activated)
- (2%) MemtoReg = ___(E)___
- (2%) ALUSrc = ___(F)___
- (2%) RegWrite. = ___(G)___ (0: inactivated, 1: activated)

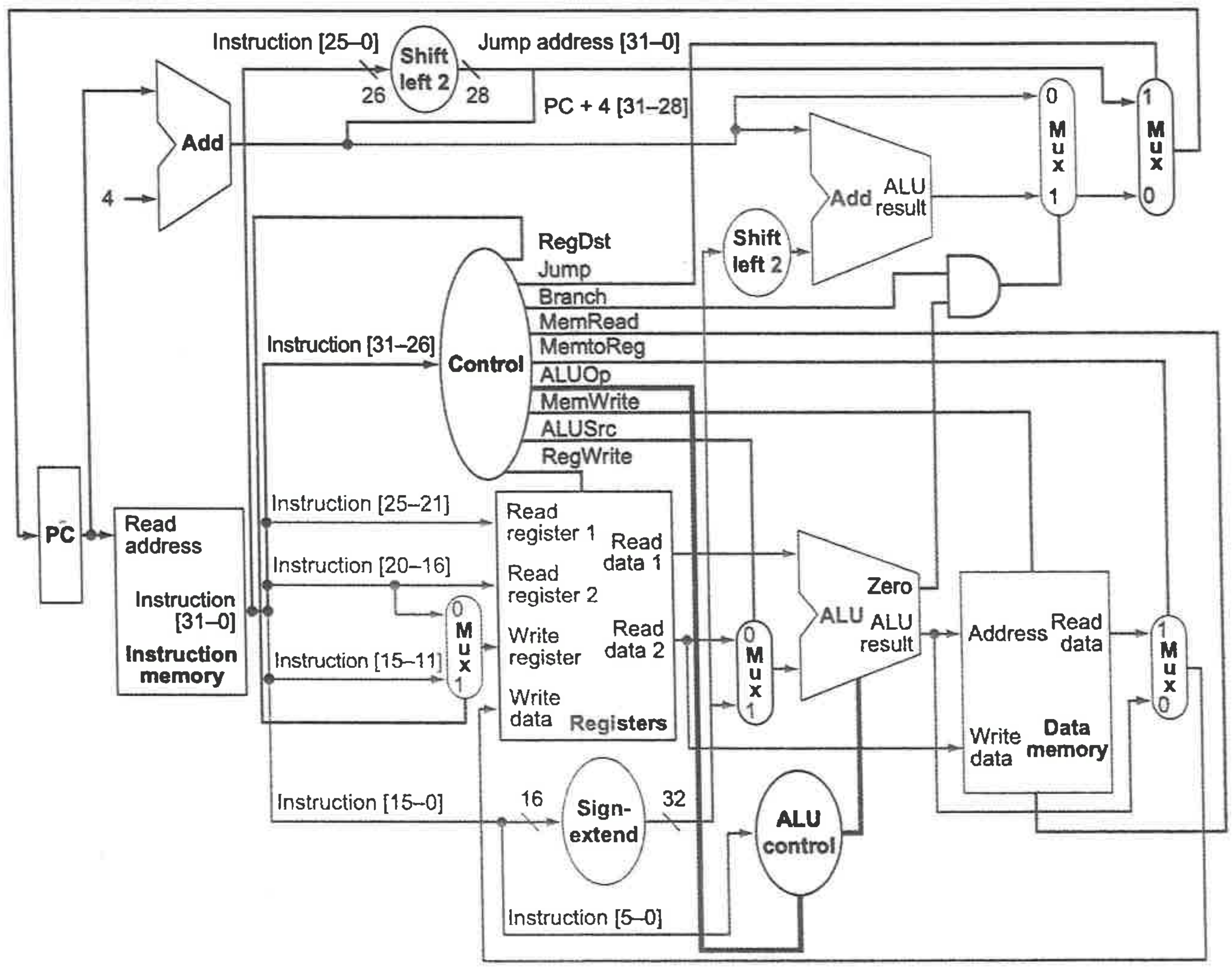

Fig. 2 MIPS single cycle processor design

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4. (15%) Compare the performance of a single-cycle processor, a multi-cycle processor, and a 5-stage pipelined processor. Assume that individual stages of the datapath have the following latencies:

IF	ID	EX	MEM	WB
250ps	350ps	150ps	300ps	200ps

Ignore the other delays in the multiplexers, wires, etc. Also, assume that instructions executed by the processor are broken down as follows:

ALU	beq	lw	sw
45%	20%	20%	15%

- (3%) Compute the clock cycle time for the single-cycle processor. __(H)__
- (3%) Compute the clock cycle time for the multi-cycle processor. __(I)__
- (3%) What is the total latency of a lw instruction in the 5-stage pipelined processor? __(J)__
- (3%) What is the total latency of a lw instruction in the single-cycle processor? __(K)__
- (3%) What is the average execution time of an instruction for the multi-cycle processor? __(L)__

5. A single-core system uses preemptive priority scheduling. All processes are CPU-bound. Context switch overhead is ignored. Smaller priority value means higher priority. The system contains the following four processes:

Process	Arrival (ms)	CPU burst (ms)	Priority
P1	0	7	2
P2	1	4	1
P3	2	5	3
P4	3	3	2

- (5%) Draw the Gantt chart and show the execution order __(M)__.
- (5%) Compute the waiting time and turnaround time of each process __(N)__, and then compute the average waiting time. __(O)__
- (5%) Does this scheduling policy cause starvation? Explain. __(P)__ Indicate whether starvation occurs in this case. __(Q)__
- (10%) Propose one OS-level method to reduce the problem described in the previous question. Briefly explain. __(R)__

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