ECE 2035 Programming HW/SW Systems Spring 2016

4 problems, 6 pages Exam One Solutions 12 February 2016

Problem 1 (2 parts, 30 points) **Loops**

Part A (12 points) Given an array `int A[100]` of **unique** unsorted integers and an integer `j` where `0 <= j < 100`, write a C fragment to calculate the `index (0 <= index < 100)` that element `A[j]` would have in the array if the array were sorted from smallest to largest. ***For maximum credit, declare and initialize any necessary variables.***

```
int j = … ;  // given
int A[100] = {22,-41,10001,...42}; // given
int index = 0;
int i;
for (i = 0; i<100; i++)
   {
      if (A[i] < A[j])
         {
            index++;
         }
   }
```

Part B (18 points) Write MIPS code for the fragment in Part A. **Assume `j` is given in register $1. Store the `index` computed in register $2**. *For maximum credit use a minimum number of instructions.*

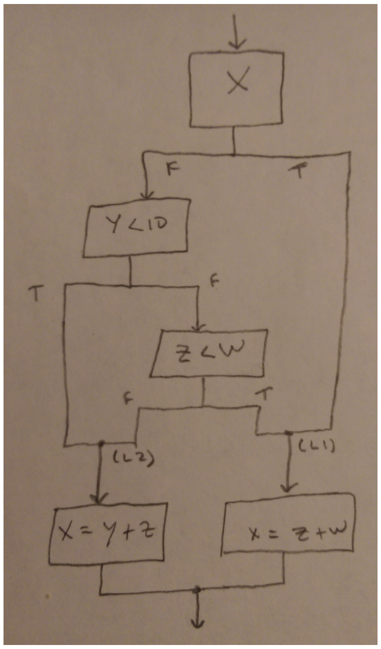
Label	Instruction	Comment
	.data	#
A:	.word 22, -41, 10001, …, 42	# given set A
	.text	#
	addi $1, $0, …	# given j
	addi $2, $0, 0	**# initialize index**
	addi $3, $0, 0	**# initialize loop counter**
	sll $1, $1, 2	**# scale j by 4 to look up A[j]**
	lw $5, A($1)	**# $5: A[j]**
Loop:	**slti $4, $3, 400**	**# is loop counter < limit?**
	beq $4, $0, Exit	**# if not, exit loop**
	lw $6, A($3)	**# lookup current element of A**
	slt $4, $6, $5	**# is A[i] < A[j]?**
	beq $4, $0, Skip	**# if not, Skip increment**
	addi $2, $2, 1	**# increment index**
Skip:	**addi $3, $3, 4**	**# increment loop counter**
	j Loop	**# continue looping**
Exit:	**jr $31**	#

Problem 2 (2 parts, 24 points) **Conditionals: Compound Predicates**

For the following MIPS code, assume that $1, $2, $3, and $4 are assigned to integers x, y, z and w respectively.

```
start:      bne   $1, $0, L1
            slti  $5, $2, 10
            bne   $5, $0, L2
            slt   $5, $3, $4
            beq   $5, $0, L2
L1:         add   $1, $3, $4
      j     end
L2:         add   $1, $2, $3
end:
```

Part A (12 points) Draw the control flow graph for the MIPS code shown.



Part B (12 points) Write the C code that corresponds to the above MIPS code with only one `if` statement (not nested) and only one compound predicate.

```
if (x || ((y>=10) && (z<w)))
  x = z+w;
else
  x = y+z;
```

OR

```
if (!x && ((y<10) || (z>=w)))
  x = y+z;
else
  x = z+w;
```

Problem 3 (4 parts, 21 points) **MIPS Equivalences**

Part A (3 points) Write a **single** MIPS instruction that is equivalent to the original fragment.

Original:	Equivalent MIPS statement:
`ori $3, $0, SetA`	**`addi $4, $1, SetA`**
`add $4, $3, $1`	

Part B (6 points) Write a **single** MIPS instruction that is equivalent to the original fragment. Assume *little endian* byte ordering.

Original:	Equivalent MIPS statement:
`lui  $4, 0xFF00`	
`lw   $3, 1000($0)`	**`lbu $3, 1003($0)`**
`and  $3, $3, $4`	
`srl  $3, $3, 24`	

Part C (6 points) Write a MIPS fragment with **at most 2 instructions** that is equivalent to the original fragment.

Original:	Equivalent MIPS in **two** instructions only:
`slt $3, $2, $1`	**`slt $3, $1, $2`**
`bne $3, $0, Target`	**`beq $3, $0, Target`**
`beq $1, $2, Target`	

Part D (6 points) What hexadecimal value will be in register $2 when this MIPS fragment executes? Assume *little endian* byte ordering.

```
lui $1, 0xABCD
ori $1, $1, 0x1234
sw  $1, 1000($0)
lb  $2, 1002($0)    # note this is lb, not lbu
```

Register $2: **`0xFFFFFFCD`**

Problem 4 (2 parts, 25 points) **Nonlocal Control Flow**

Part A (12 points) What does the following code fragment print?

```
int i, x;
int A[10] = {99, 33, 44, 22, 56, 78, 1, 5, 9, 88};

for(i=0; i<10; i++){
  if(i & 1)              \\ bitwise
     continue;
  x = A[i];
  printf("x = %d\n", x);
}
```

```
x = 99
x = 44
x = 56
x = 1
x = 9
```

Fill in the blanks to rewrite the code above to produce the equivalent behavior without using `continue`.

```
int i;
int A[] = {99, 33, 44, 22, 56, 78, 1, 5, 9, 88};

for(__i=0__; ___i<10____; _i += 2_){
  x = A[i];
  printf("x = %d\n", x);
}
```

Part B (13 points) Answer the three questions below about the following C fragment.

```
int A[4] = {1, 10, 100, 1000};
int B[4] = {2, 4, 8, 16};
int i, j, k;

for (i = 0; i<4; i++)                          \\ outer loop
   {
    for (j = 0; j<4; j++)                      \\ middle loop
       {
          if (j == 2)
           break;

          for (k = 0; k<4; k++)                \\ inner loop
           {
              if (k == 1)
                 continue;
              printf("%d\n", A[i]*B[k]);
           }
       }
   }
```

How many times is `break` executed?	**4**
How many times is `continue` executed?	**8**
How many `printf` statements are executed?	**24**