CS261: Midterm Exam 2

NAME: ______________________________

INSTRUCTIONS

- This is a 45 minute, closed-book exam containing **THREE** problems
- Look at the back of the exam for the C code for Problems 1 and 3
- Cases of academic dishonesty will be filed to the Office of Student Conduct

Problems	Max points	Earned points
1.1	10	
1.2	30	
2	24	
3	36	
TOTAL	100	

Problem 1. Hash Table with Singly Linked Lists – 10 points + 38 points

Problem 1.1. Pseudo Code – 10 points

Write a pseudo code for adding a new element to a hash table with singly linked lists. The element consists of the key and value. The hash table keeps the record of a total number of elements.

Solution:

1) (2 points) Use the hashing function to compute the index of the list where to add the new element to the table from the element's key.
2) (2 points) Allocate memory to a new link, and assign the element's value to this link
3) (2 points) Add the new link to the list at index; the new link goes to the front of the list
4) (2 points) Increment the total number of elements in the table
5) (2 points) Check if the loading factor is less than a threshold; if yes, call the function for doubling the size of the table

Problem 1.2. C Implementation – 30 points

Write a function in C for adding a new element to a hash table with singly linked lists, `addHT()`. **You may use only your functions, built-in C functions, and the C code provided for Problem 1.** Please do not modify the names of data types, variables, and functions that we provided.

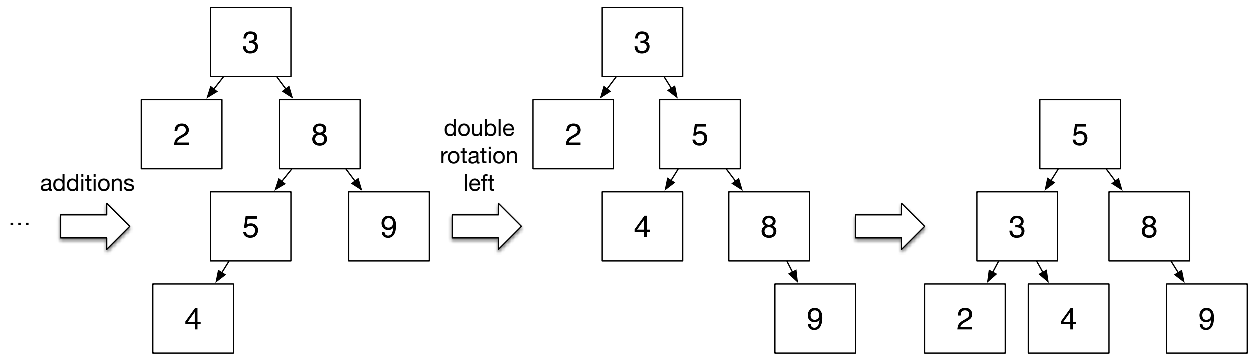
```
/* Add a data element to a Hash Table */
/* Input:
   ht -- pointer to a hash table with singly linked lists
   elem -- element to be added to the hash table consisting of the key and value.
*/


void addHT (struct HashTable * ht, struct DataElem elem) {

   /* FIX ME */


   float loadFactor;
   assert(ht);


   /*(4 points) compute the right index of the element*/

   int hashIndex = (int) (abs(HASH(elem.key)) % ht->tablesize);


   /*(4 points) allocate memory to the element*/

   struct Link * newLink = (struct Link *) malloc(sizeof(struct Link));

   assert(newLink);


   /*(2 points) assign the value to the new link*/

   newLink->elem = elem;


   /*(8 points) connect the new link to the list at the front*/

   newLink->next = ht->table[hashIndex];

   ht->table[hashIndex] = newLink;


   /*(4 points) update the number of elements in the hash table */

   ht->count++;

   /*(8 points) Check the loading factor, and  resize if necessary  */

   loadFactor = ht->count / ht->tablesize;

   if ( loadFactor > MAX_LOAD_FACTOR ) _resizeHT(ht);

}
```

Problem 2. AVL Tree – 24 points

The main function of a C code, first, initializes an AVL tree, then, adds the sequence of numbers {3, 2, 8, 5, 9, 4} to the AVL tree, and, finally, prints all node values of the resulting AVL tree in the pre-order fashion.

1) (12 points) Draw by hand the resulting AVL tree,
2) (12 points) Write the output of this main function.

<u>Solution:</u>



The pre-order printout: 5, 3, 2, 4, 8, 9

Grading:

- (2 points) The drawing of the final AVL tree has more than one node wrongly placed/connected in the AVL tree, or

- (5 points) The drawing of the final AVL tree has only one node wrongly placed/connected in the AVL tree, or

- (12 points) The drawing of the final AVL tree is correct, and

- (maximum 12 points) For grading the pre-order printout, take the student's drawing of the AVL tree as correct. If it is different from my solution, then you will have to derive the pre-order printout for the student's AVL tree. Then, compare your pre-order printout with the student's as follows. First, count from left to right how many consecutive numbers are correctly printed until the first wrong number, and then multiply that count by 2.

Problem 3: BST2AVL – 36 points

Write the C function, `bst2avl()`, for balancing the height of **all nodes** in the input binary search tree (BST). **You may use only your functions, built-in C functions, and the C code provided for Problem 3.** Please do not modify the names of data types, variables, and functions that we provided.

```
/* Transforms the input BST to the corresponding AVL tree */
/* Input: tree -- binary search tree
   Post: tree -- points to the corresponding AVL tree
*/
void bst2avl(struct Tree *tree){
  assert(tree);

  /* FIX ME */

  /* (5 points) */
  tree->root = _balanceAll(tree->root);
}



/*
The two key ideas:
   1. We have to balance the nodes bottom up from leaves to the root.
   Therefore, we need to implement a function that recursively balances
   the height of all nodes in a BST in the post-order manner (depth-first)

   2. Whenever the current node requires a rotation, we need to re-balance
   the entire subtree below the current to handle extreme cases of BST,
   e.g., when BST is just a long linked list. Therefore, we need to implement a
   while loop that runs as long as the current node requires a rotation.
 */

/*  (5 points) Specifying the name and input of the auxiliary recursive function */
struct Node * _balanceAll(struct Node *current)
{
   struct Node *tmp; /* remembers current */

   /* (5 points) Check the stopping criterion of the recursion */
   while(current)
   {
     tmp = current;

     /* (5 points) balance the left subtree */
     current->left =  _balanceAll(current->left);

     /* (5 points) balance the right subtree */
     current->right =  _balanceAll(current->right);  /* 5 points */

     /* (6 points) balance the current node */
     current = balanceNode(current);  /* current changes here if it had to be rotated */
     if (tmp == current) return current;  /* exit loop if current did not require a rotation */
   }
   /* (5 points) Stop recursion */
   return NULL;

}
```

C Code for Problem 1

```
#define TYPE_KEY char
#define TYPE_VALUE double
#define MAX_LOAD_FACTOR 10

struct HashTable {
  struct Link **table;/*Array of lists*/
  int count;/*number of elements*/
  int tablesize;/*number of lists*/
}

struct Link {
   struct DataElem elem;
   struct Link * next;
}
```

```
struct DataElem {
   TYPE_KEY key[100];
   TYPE_VALUE value;
}

/* The hash function */
int HASH(TYPE_KEY * key){
   int i;
   int index = 0;
   for (i = 0; key[i] != ’\0’; i++)
      index += key[i];
   return index;
}
```

```
/* Double the size of a hash table with singly linked lists
      input: ht -- pointer to the hash table
      pre: the input hash table exists in the memory, and was initialized,
      post: the hash table size has doubled
*/
void _resizeHT(struct HashTable *ht) {
   int oldsize = ht->tablesize;
   struct HashTable *oldht = ht; /* old table */
   struct Link *cur, *last;
   int i;

   /* Allocate new memory with double the size, and initialize */
   ht->table = (struct Link **) malloc(sizeof(struct Link *) * (2 * oldsize));
   assert(ht->table != 0);
   ht->tablesize = 2 * oldsize;
   ht->count = 0;
   for(i = 0; i < ht->tablesize; i++)   ht->table[i] = 0;

   /* Copy the old hash table */
   for( i = 0; i < oldsize; i++) {
      cur= oldht->table[i];
      while(cur != 0){
         addHT(ht, cur->elem);
         /* remove the old link */
         last = cur;
         cur = cur->next;
         free(last);
      }
   }
   /* Free old table */
   free(oldht);
}
```

C Code for Problem 3

```c
# define TYPE int

struct Node {
  TYPE   val;
  struct Node *left;
  struct Node *right;
  int height;
};

struct Tree {
  struct Node *root;
  int size;
};

/* return height of current*/
int height(struct Node *current){
  if (current == 0) return -1;
  return current->height;
}

/* set height for current node */
void setHeight (struct Node * current){
  int lch = height(current->left);
  int rch = height(current->right);
  if (lch < rch)
    current->height = 1 + rch;
  else
    current->height = 1 + lch;
}

/* rotate right current node */
struct Node * rotateRight(struct Node * current){
  struct Node * new = current->left;
  current->left = new->right;
  new->right = current;
  setHeight(current);
  setHeight(new);
  return new;
}

/* rotate left current node */
struct Node * rotateLeft (struct Node * current){
  struct Node * newtop = current->right;
  current->right = newtop->left;
  newtop->left = current;
  setHeight(current);
  setHeight(newtop);
  return newtop;
}
```

C Code for Problem 3 (continued)

```
/* Balance the height of the input node */
struct Node * balanceNode (struct Node * current){
   assert(current);
   /*  compute rotation flags */
   int rotation = height(current->right) - height(current->left);
   int dRotationRight = height(current->left->right) - height(current->left->left);
   int dRotationLeft = height(current->right->left) - height(current->right->right);

   if (rotation < -1)
   {
     /* right rotation */
     /* check if double rotation is needed */
     if (dRotationRight > 0) {
        /* rotate left current's left child*/
        current->left = rotateLeft(current->left);
     }
     /* return the balanced node */
     return rotateRight(current);
   }
   else if(rotation > 1)
   {
     /* left rotation */
     /* check if double rotation is needed  */
     if( dRotationLeft > 0 ){
        /* rotate right current's right child */
       current->right = rotateRight(current->right);
     }
     /* return the balanced node */
     return rotateLeft(current);
   }

   /* return current unchanged */
   return current;
}
```