SCHOOL OF COMPUTER SCIENCES
UNIVERSITI SAINS MALAYSIA
Semester II, Session 2023/2024

CPT113 – Programming Methodology & Data Structure
Tutorial Week 10
Doubly and Circular Linked Lists

Learning Outcomes:

- Understanding the use of doubly and circular linked lists in class

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1. Given the following linked list header file, modify the codes to make it a doubly linked list. Then, write a short main program to test the various functionalities (append, insert, delete, display).

```
// A class template for holding a linked list.
#ifndef LINKEDLIST_H
#define LINKEDLIST_H
#include <iostream>
using namespace std;
template <class T>
class LinkedList
{
      private:
            // Declare a structure for the list
            struct ListNode
            {
                  T value; // The value in this node
                  ListNode *next; // To point to the next node
            };

            ListNode *head; // List head pointer

      public:
            // Constructor
            LinkedList()
            { head = nullptr; }
            // Destructor
            ~LinkedList();
            // Linked list operations
            void appendNode(T);
            void insertNode(T);
            void deleteNode(T);
            void displayList() const;
};
```

```
//************************************************
// appendNode appends a node containing the value *
// pased into newValue, to the end of the list. *
//************************************************

template <class T>
void LinkedList<T>::appendNode(T newValue)
{
      ListNode *newNode; // To point to a new node
      ListNode *nodePtr; // To move through the list
      // Allocate a new node and store newValue there.
      newNode = new ListNode;
      newNode->value = newValue;
      newNode->next = nullptr;
      // If there are no nodes in the list
      // make newNode the first node.
      if (!head)
            head = newNode;
      else // Otherwise, insert newNode at end.
      {
            // Initialize nodePtr to head of list.
            nodePtr = head;
            // Find the last node in the list.
            while (nodePtr->next)
                  nodePtr = nodePtr->next;
            // Insert newNode as the last node.
            nodePtr->next = newNode;
      }
}



//************************************************
// displayList shows the value *
// stored in each node of the linked list *
// pointed to by head. *
//************************************************
template <class T>
void LinkedList<T>::displayList() const
{
      ListNode *nodePtr; // To move through the list
      // Position nodePtr at the head of the list.
      nodePtr = head;
      // While nodePtr points to a node, traverse the list.
      while (nodePtr)
      {
            // Display the value in this node.
            cout << nodePtr->value << endl;
            // Move to the next node.
            nodePtr = nodePtr->next;
      }
}
```

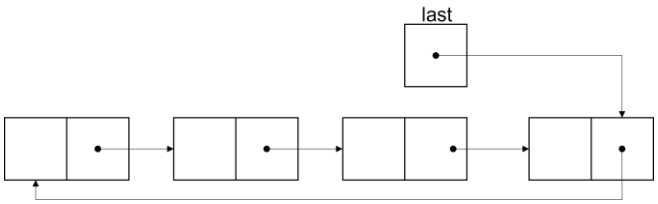
```
//************************************************
// The insertNode function inserts a node with *
// newValue copied to its value member. *
//************************************************

template <class T>
void LinkedList<T>::insertNode(T newValue)
{
      ListNode *newNode; // A new node
      ListNode *nodePtr; // To traverse the list
      ListNode *previousNode = nullptr; // The previous node
      // Allocate a new node and store newValue there.
      newNode = new ListNode;
      newNode->value = newValue;
      // If there are no nodes in the list
      // make newNode the first node
      if (!head)
      {
            head = newNode;
            newNode->next = nullptr;
      }
      else // Otherwise, insert newNode
      {
            // Position nodePtr at the head of list.
            nodePtr = head;
            // Initialize previousNode to nullptr.
            previousNode = nullptr;
            // Skip all nodes whose value is less than newValue.
            while (nodePtr != nullptr && nodePtr->value < newValue)
            {
                  previousNode = nodePtr;
                  nodePtr = nodePtr->next;
            }
            // If the new node is to be the 1st in the list,
            // insert it before all other nodes.
            if (previousNode == nullptr)
            {
                  head = newNode;
                  newNode->next = nodePtr;
            }
            else // Otherwise insert after the previous node.
            {
                  previousNode->next = newNode;
                  newNode->next = nodePtr;
            }
      }
}
```

```
//**************************************************
// The deleteNode function searches for a node *
// with searchValue as its value. The node, if found, *
// is deleted from the list and from memory. *
//**************************************************
template <class T>
void LinkedList<T>::deleteNode(T searchValue)
{
      ListNode *nodePtr; // To traverse the list
      ListNode *previousNode; // To point to the previous node
      // If the list is empty, do nothing.
      if (!head)
            return;
      // Determine if the first node is the one.
      if (head->value == searchValue)
      {
            nodePtr = head->next;
            delete head;
            head = nodePtr;
      }
      else
      {
            // Initialize nodePtr to head of list
            nodePtr = head;
            // Skip all nodes whose value member is
            // not equal to num.
            while (nodePtr != nullptr && nodePtr->value != searchValue)
            {
                  previousNode = nodePtr;
                  nodePtr = nodePtr->next;
            }
            // If nodePtr is not at the end of the list,
            // link the previous node to the node after
            // nodePtr, then delete nodePtr.
            if (nodePtr)
            {
                  previousNode->next = nodePtr->next;
                  delete nodePtr;
            }
      }
}
```

```
//************************************************
// Destructor *
// This function deletes every node in the list. *
//************************************************
template <class T>
LinkedList<T>::~LinkedList()
{
      ListNode *nodePtr; // To traverse the list
      ListNode *nextNode; // To point to the next node
      // Position nodePtr at the head of the list.
      nodePtr = head;
      // While nodePtr is not at the end of the list...
      while (nodePtr != nullptr)
      {
            // Save a pointer to the next node.
            nextNode = nodePtr->next;
            // Delete the current node.
            delete nodePtr;
            // Position nodePtr at the next node.
            nodePtr = nextNode;
      }
}
#endif
```

2. An illustration of a circular linked list is shown below. Rather than having a pointer to the first node in the list, we use a pointer called last to point to the last node in the list.



The incomplete header file for the circular linked list is provided below:

```
// A class template for holding a circular linked list.
#ifndef CIRCLIST_H
#define CIRCLIST_H
#include <iostream>     // For cout
using namespace std;

template <class T>
class CircList
{
     private:
              // Declare a structure for the list
              struct ListNode
              {
                     T value;                // The value in this node
                     ListNode *next;  // To point to the next node
              };

              ListNode *last;   // Pointer for last node in the circular linked list

     public:
              // Constructor
              CircList()
              { last = nullptr; }

              // Destructor
              ~CircList();

              // Linked list operations
              void appendNode(T);
              void deleteNode(T);
              void displayList() const;
};

//************************************************
// appendNode appends a node containing the value  *
// pased into newValue, to the end of the list.    *
//************************************************

template <class T>
void CircList<T>::appendNode(T newValue)
{
   //Incomplete function
}

//************************************************
// displayList shows the value                    *
// stored in each node of the linked list         *
// pointed to by first.                            *
//************************************************

template <class T>
void CircList<T>::displayList() const
{
   ListNode *nodePtr;  // To move through the list
```

```
   // Position nodePtr at the first of the list.
   nodePtr = last->next;

   // While nodePtr points to a node, traverse
   // the list.
   do
   {
      // Display the value in this node.
      cout << nodePtr->value << endl;
      // Move to the next node.
      nodePtr = nodePtr->next;
   } while (nodePtr != last->next);
}

//*****************************************************
// The deleteNode function searches for a node        *
// with searchValue as its value. The node, if found, *
// is deleted from the list and from memory.          *
//*****************************************************

template <class T>
void CircList<T>::deleteNode(T searchValue)
{
   //Incomplete code
}


//************************************************
// Destructor                                    *
// This function deletes every node in the list.   *
//************************************************

template <class T>
CircList<T>::~CircList()
{
   ListNode *nodePtr;   // To traverse the list
   ListNode *nextNode;  // To point to the next node

   // Position nodePtr at the first of the list.
   nodePtr = last->next;

   // If there is only one node in the list
   if (nodePtr == last)
      delete nodePtr;

   else {
   // While nodePtr is not at the end of the list...
      do
      {
         // Save a pointer to the next node.
         nextNode = nodePtr->next;

         // Delete the current node.
         delete nodePtr;

         // Position nodePtr at the next node.
         nodePtr = nextNode;
      } while (nodePtr!=last);
      delete last;
   }
}

#endif
```

(a) How would assign the address of the first node to a pointer called `nodePtr`?

(b) The following is the implementation of the appendNode function for a regular linked list. Modify the function so that a new node will be appended to the end of the circular linked list shown above.

```
template <class T>
void LinkedList<T>::appendNode(T newValue)
{
     ListNode<T> *newNode; // To point to a new node
     ListNode<T> *nodePtr; // To move through the list

     // Allocate a new node and store newValue there.
     newNode = new ListNode;
     newNode->value = newValue;
     newNode->next = nullptr;

     // If there are no nodes in the list, make newNode the first node.
     if (!head)
            head = newNode;

     else // Otherwise, insert newNode at end.
     {
            // Initialize nodePtr to head of list.
            nodePtr = head;

            // Find the last node in the list.
            while (nodePtr->next)
            nodePtr = nodePtr->next;

            // Insert newNode as the last node.
            nodePtr->next = newNode;
     }
}
```

(c) Complete the `deleteNode` function. Note that you will need to take the following scenarios into consideration:

- Empty list which has nothing to delete
- The first node is the one to be deleted
- The last node is the one to be deleted
- The node to be deleted is neither the first nor last node

Test your code with the following main function:

```
int main() {
     //Create two different linked lists, one for int, one for double
     CircList<int> list1;

     list1.appendNode(2);
     list1.appendNode(3);
     list1.displayList();
     cout << "After deleting first node\n";
     list1.deleteNode(2);
     list1.displayList();
     cout << "---\n";

     list1.appendNode(4);
     list1.appendNode(5);
     list1.displayList();
     cout << "After deleting middle node\n";
     list1.deleteNode(4);
     list1.displayList();
```

```
     cout << "---\n";

     list1.appendNode(6);
     list1.appendNode(7);
     list1.displayList();
     cout << "After deleting last node\n";
     list1.deleteNode(7);
     list1.displayList();
     cout << "---\n";

    return 0;
}
```

Your output should be as follows:

```
2
3
After deleting first node
3
---
3
4
5
After deleting middle node
3
5
---
3
5
6
7
After deleting last node
3
5
6
```