INTRODUCTION

In this week we cover the following topics

6.1 LISTS

- A list is a set of structures, each containing
  - One or more pointers to act as *links.*
  - At least one data item to act as a *key* for searching or sorting the list.
  - Any other data.

- We also need a pointer to the head of the list and it may be useful to have a pointer to the tail of the list.

- This is an application that combines classes and pointers. While not as fast as vectors they are very flexible in the way they can grow and shrink. Lists and their variants are "natural" data structures in that the concepts behind them are the basis for more sophisticated data structures.

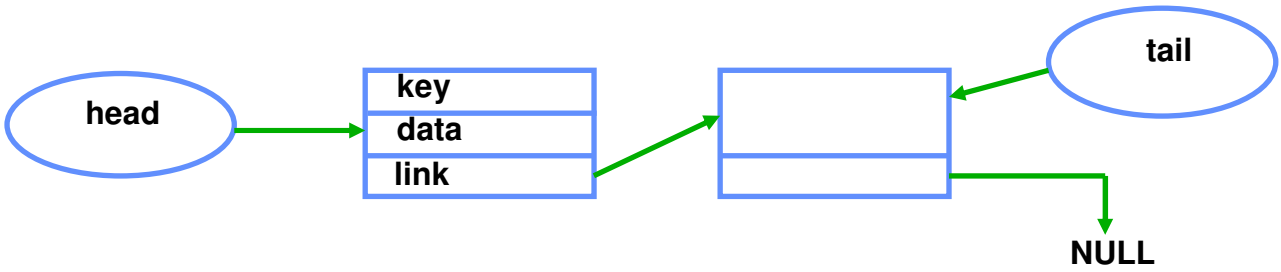
- Basic problems:
  - Maintaining linkages
  - Adding and removing items
  - Finding items in the list.

  Mechanisms to achieve this range from simple to complex.

6.1.1 Singly-Linked Lists

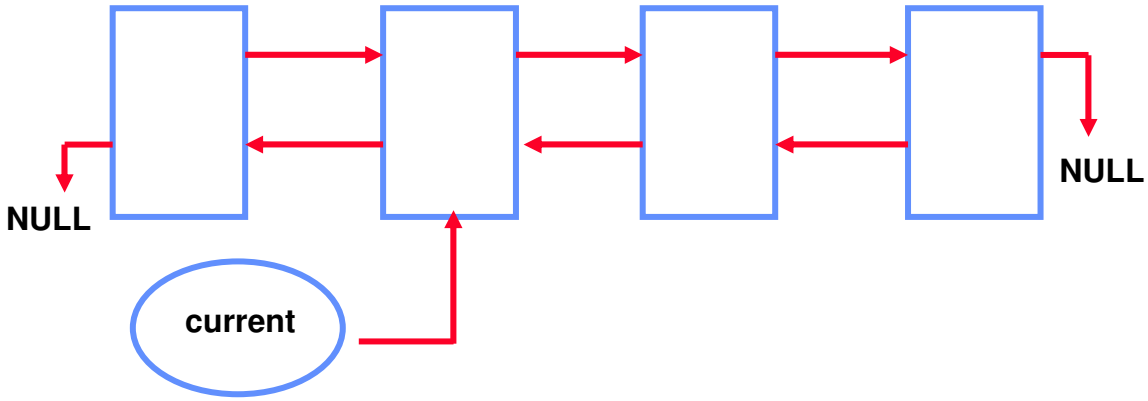
- Each item points to the next.
- Tail pointer is optional, makes it easier to add to tail.
- Items can be added or removed anywhere in list
  - (But you have to search along the list to find insertion point)
- Last item's pointer is `NULL`, signifies end of list

- If `head` and `tail` pointers are `NULL`, list is empty



6.1.2 Doubly-Linked Lists

- Each node contains two pointers
  - One points to right
  - The other points left
- Because we can walk the list in both directions, only one pointer is needed to manage the list.



- Some operations are simpler.
- Some operations are faster.
- Most operations are more complex.
- Code is harder to understand, harder to debug.

6.2 FRIEND CLASSES

- There are times when you want a class to be able to directly access the private data and functions of another class.

- This can be achieved by making one class a *friend* of another. The friend class is able to directly access the private data.

- The following example illustrates.

```
class xyz
{
   friend abc;

   private:
      int x;
};

class abc
{
   private:
      int a;

   public:
      void seta(xyz &foo) {
         a = foo.x;
      }
};
```

If `abc` was not a friend of `xyz` then the line `a = foo.x;` would not compile because `x` is private in `xyz`.

6.3 ITERATORS

- Since we want to create generic template data structures, we come across the issue of searching through template lists.

- We want a search mechanism that is generic in the same way as the linked list. The method for doing this is to create a template object called an *iterator* and include an instance of this in the declaration of the linked list.

- The iterator has functions for taking us to the beginning and end of the list, plus overloads the increment and decrement operators to allow us to move back and forth along the list.

6.4 dlist.h

```
sally% cat dnode.h

#ifndef DNODE_H
#define DNODE_H

/*************************************************\
   template node class for doubly linked list
\*************************************************/

template <typename dataType> struct dnode
{
   dataType data;
   dnode *prev, *next;

   // constructors
   dnode() : prev(NULL), next(NULL) {
   }

   dnode(const dataType& dataItem,
         dnode *prevPtr, dnode *nextPtr) :
            data(dataItem), prev(prevPtr),
            next(nextPtr) {
   }
};

#endif
```

```
// ##############################################

sally% cat dlistIterator.h
#ifndef DLISTITERATOR_H_
#define DLISTITERATOR_H_

#include "dnode.h"

/*********************************************\
   template iterator class for doubly linked
   list class
\*********************************************/

template <typename dataType> class dlistIterator
{
   friend class dlist<dataType>;

   private:
      dlist<dataType> *parent;
      dnode<dataType> *current;

   public:

      // constructor
      dlistIterator(dlist<dataType> *myParent,
         dnode<dataType> *position) :
         parent(myParent), current(position) {
      }

      // overloaded dereference operator
      dataType& operator * () const {
         if (current == NULL) {
            throw std::invalid_argument(
                "Attempting to dereference NULL
                in dlistIterator");
         }
         return current->data;
      }
```

```
        // overloaded arrow operator
        dataType* operator -> () const {
           if (current == NULL) {
              throw std::invalid_argument(
                  "Attempting to dereference NULL
                   in dlistIterator");
           }
           return &(current->data);
        }

        // overloaded prefix increment operator
        dlistIterator<dataType> operator ++ () {
           if (current == NULL) {
              throw std::invalid_argument(
                  "Attempting to advance past end
                   in dlistIterator");
           }
           current = current->next;
           return *this;
        }

        // overloaded postfix increment operator
        dlistIterator<dataType> operator ++ (int) {
           dlistIterator<dataType>
                current_data = *this;
           ++(*this);
           return current_data;
        }

        // overloaded equality operator
        bool operator ==
           (const dlistIterator &other) {
           return current == other.current;
        }

        // overloaded inequality operator
        bool operator !=
           (const dlistIterator &other) {
           return current != other.current;
        }
};

#endif
```

```
// ##############################################

sally% cat dlist.h

#ifndef DLIST_H_
#define DLIST_H_

#include <stdexcept>

template <typename dataType> class dlist;

#include "dnode.h"
#include "dlistIterator.h"
#include "dlistConstIter.h"


/*********************************************\
   template class for doubly linked list
\*********************************************/


template <typename dataType> class dlist
{
   private:
      dnode<dataType> *head, *tail;
      int numItems;

   public:
      /*****************************************\
         iterator friendship and functions
      \*****************************************/

      friend class dlistIterator<dataType>;
      friend class dlistConstIter<dataType>;

      dlistIterator<dataType> begin() {
         return
            dlistIterator<dataType>(this, head);
      }

      dlistConstIter<dataType> begin() const {
         return
           dlistConstIter<dataType> (this, head);
      }
```

```
dlistIterator<dataType> end() {
   return
      dlistIterator<dataType>(this, NULL);
}

/*****************************************\
   constructor and destructor functions
\*****************************************/

// default constructor
dlist() :
   head(NULL), tail(NULL), numItems(0) {
}

// copy constructor
dlist(const dlist<dataType> &other) :
   head(NULL), tail(NULL), numItems(0) {
   for (dlistConstIter<dataType>
         itr = other.begin();
         itr != other.end(); itr++) {
      push_back(*itr);
   }
}

// destructor
~dlist() {
   while(head != NULL) {
      // delete every dnode in list
      dnode<dataType> *current = head;
      head = head->next;
      delete current;
   }
}

/*****************************************\
   misc functions
\*****************************************/

void swap(dlist<dataType> &other) {
   std::swap(numItems, other.numItems);
   std::swap(head, other.head);
   std::swap(tail, other.tail);
}
```

```
bool empty() {
   return (numItems == 0);
}

int size() {
   return numItems;
}

bool find(const dataType &findData,
          dlistIterator<dataType> &itr)
{
   // function for finding something
   // in a dlist

   for (itr = begin();
        itr != end(); itr++) {
      if (*itr == findData) return true;
   }
   return false;
}

/*****************************************\
   push and insertion functions
\*****************************************/

void push_front(const dataType &item) {
   head =
     new dnode<dataType>(item, NULL, head);
   if (!empty()) {
      head->next->prev = head;
   }
   else
   {
      tail = head;
   }
   numItems++;
}
```

```
void push_back(const dataType &item) {
   if (!empty()) {
      tail->next = new dnode<dataType>
                   (item, tail, NULL);
      tail = tail->next;
      numItems++;
   } else {
      push_front(item);
   }
}

dlistIterator<dataType>
     insert(dlistIterator<dataType> pos,
     const dataType &item) {
   if (pos.current == head) {
      push_front(item);
      return begin();
   } else if (pos.current == NULL) {
      push_back(item);
      return dlistIterator<dataType>
                  (this, tail);
   } else {
      dnode<dataType> *newNode =
         new dnode<dataType>
           (item, pos.current->prev,
            pos.current);
      pos.current->prev->next = newNode;
      pos.current->prev = newNode;
      numItems++;
      return dlistIterator<dataType>
                   (this, newNode);
   }
}

/*****************************************\
   pop and erase functions
\*****************************************/
```

```
void pop_front() {
   if (empty()) {
      throw std::invalid_argument
          ("Attempting to pop front of
            empty list");
   }

   // slice out the front node
   dnode<dataType> *removeNode = head;
   head = head->next;
   if (head != NULL) {
      head->prev = NULL;
   } else {
      tail = NULL;
   }

   delete removeNode;
   numItems--;
}

void pop_back() {
   if (empty()) {
      throw std::invalid_argument
          ("Attempting to pop back
            of empty list");
   }

   // slice out the back node
   dnode<dataType> *removeNode = tail;
   tail =  tail->prev;
   if (tail != NULL) {
      tail->next = NULL;
   } else {
      head = NULL;
   }

   delete removeNode;
   numItems--;
}
```

```
dlistIterator<dataType>
     erase(dlistIterator<dataType> &pos) {
   if (empty()) {
      throw std::invalid_argument
         ("Attempting to erase from
           empty list");
   }
   if (pos == end()) {
      throw std::invalid_argument
         ("Attempting to erase end()");
   }

   dlistIterator<dataType>
       returnIter = pos;
   returnIter++;

   if (pos.current == head) {
      pop_front();
   } else if (pos.current == tail) {
      pop_back();
   } else {
      dnode<dataType>
            *removeNode = pos.current;
      removeNode->prev->next =
            removeNode->next;
      removeNode->next->prev =
            removeNode->prev;
      numItems--;
      delete removeNode;
   }
   return returnIter;
}

/*****************************************\
   overloaded operators
\*****************************************/

// assignment operator
dlist<dataType>& operator =
        (const dlist<dataType> &other) {
   dlist<dataType> tempCopy(other);
   swap(tempCopy);
   return *this;
}
```

```
};

#endif


// ##############################################

sally% cat testmain.cpp

/*********************************************\
   Test program for demonstrating container
   types
\*********************************************/

#include <sys/time.h>
#include <time.h>
#include <stdlib.h>
#include <iostream>
#include <algorithm>

#include "dataobject.h"
#include "dlist.h"

using namespace std;

// function prototypes
double difUtime(struct timeval *first,
                struct timeval *second);
template <typename dataType>
   dlistIterator<dataType> findData(
      dlist<dataType> &testContainer,
      const dataType &target);

double difUtime(struct timeval *first,
                struct timeval *second)
{
   // return the difference in seconds,
   // including milli seconds

   double difsec =
       second->tv_sec - first->tv_sec;

   double difmilli =
```

```
        second->tv_usec - first->tv_usec;

    return (difsec + (difmilli) / 1000000.0);
}

template<typename dataType>
    dlistIterator<dataType> findData
        (dlist<dataType> &testContainer,
         const dataType &target)
{
    /*****************************************\
       template function for finding something
       in a dlist. return an iterator positioned
       at correct place in dlist or return
       iterator positioned at end of list
    \*****************************************/


    for (dlistIterator<dataType>
              itr = testContainer.begin();
              itr != testContainer.end(); itr++) {
       if (*itr == target) return itr;
    }
    return testContainer.end();

}

int main()
{
    const int MAXDATA = 1000000;
    dataObject *doPtr;
    int i, keyvals[MAXDATA];
    dlist<dataObject> testContainer;

    // data for calculating timing
    struct timeval first, second;
    double usecs;

    try {
       /*************************************\
          Initialise things to demonstrate the
          container
          - fill keyvals and scramble it
       \*************************************/
```

```
for (i=0; i<MAXDATA; i++) keyvals[i] = i;
srand(time(NULL));
for (i=0; i<MAXDATA; i++)
    swap(keyvals[i],
    keyvals[random() % MAXDATA]);
int middle = keyvals[MAXDATA/2];

/*****************************************\
   test inserting MAXDATA data pieces into
   the container with keyval 0 to
   MAXDATA-1 in random order
\*****************************************/

gettimeofday(&first, NULL);
for (i=0; i<MAXDATA; i++) {
   doPtr = new dataObject(keyvals[i]);
   testContainer.push_back(*doPtr);
}
gettimeofday(&second, NULL);
usecs = difUtime(&first, &second);
cout << MAXDATA <<
   " items in container in random order\n";
cout << "time taken to push data into
  container = " << usecs << " seconds\n\n";

/*****************************************\
   test finding data in the container
\*****************************************/

gettimeofday(&first, NULL);
findData(testContainer,
         dataObject(keyvals[0]));
gettimeofday(&second, NULL);
usecs = difUtime(&first, &second);
cout << "time taken to find first item in
    container = " << usecs << " seconds\n";

gettimeofday(&first, NULL);
dlistIterator<dataObject> itr =
   findData(testContainer,
            dataObject(keyvals[middle]));
gettimeofday(&second, NULL);
usecs = difUtime(&first, &second);
```

```
    cout << "time taken to find item in middle
     of container = " << usecs << " seconds\n";

    gettimeofday(&first, NULL);
    findData(testContainer,
                dataObject(MAXDATA));
    gettimeofday(&second, NULL);
    usecs = difUtime(&first, &second);
    cout << "time taken to find item doesn't
         exit in container = " << usecs <<
         " seconds\n\n";

    /*****************************************\
       test removing data from the container
    \*****************************************/

    gettimeofday(&first, NULL);
    testContainer.pop_front();
    gettimeofday(&second, NULL);
    usecs = difUtime(&first, &second);
    cout << "time taken to erase first item in
        container = " << usecs << " seconds\n";

    gettimeofday(&first, NULL);
    testContainer.erase(itr);
    gettimeofday(&second, NULL);
    usecs = difUtime(&first, &second);
    cout << "time taken to erase middle item in
        container = " << usecs << " seconds\n";

    gettimeofday(&first, NULL);
    testContainer.pop_back();
    gettimeofday(&second, NULL);
    usecs = difUtime(&first, &second);
    cout << "time taken to erase last item in
       container = " << usecs << " seconds\n";
}
catch (out_of_range &ex) {
    cout << "\nERROR - Out of Range Exception
          thrown\n" << ex.what() << "\n";
    exit(1);
}
```

```
   catch(...) {
      cout << "\nERROR - undefined Exception
            thrown\n";
      exit(1);
   }

   return 0;
}

// ###############################################

sally% cat makefile
CC = g++
prog: testmain.o
    $(CC) testmain.o -Wall -o testmain
testmain.o: testmain.cpp dlist.h dataobject.h
    $(CC) -Wall -c testmain.cpp


sally% testmain
1000000 items in container in random order
time taken to push data into container = 2.99964
seconds

time taken to find first item in container =
0.067085 seconds
time taken to find item in middle of container =
0.603338 seconds
time taken to find item doesn't exit in container
= 1.23745 seconds

time taken to erase first item in container =
9.1e-05 seconds
time taken to erase middle item in container =
8e-06 seconds
time taken to erase last item in container =
4e-06 seconds
```