

List implementation in C++

- many times in Computer Science we need to maintain dynamically adjustable lists
- consider the following C function definitions

```

/*
 * create an empty list.
 *   pre-condition: none.
 *   post-condition: returns an empty list.
 */
list empty (void);

```

List specification

```

/*
 * is_empty
 *   pre-condition: an initialised list.
 *   post-condition: returns true if list is empty.
 */
bool is_empty (list l);

```

List specification

```

/*
 * cons
 *   pre-condition: an initialised list.
 *   post-condition: adds, i, to the end of list, l.
 */
list cons (list l, int i);

```

List specification

```

/*
 * head
 *   pre-condition: an initialised list containing 1 or more
 *                   elements.
 *   post-condition: returns the data associated with the
 *                   element, the list is unaltered.
 */
int head (list l);

```

List specification

```

/*
 * tail
 *   pre-condition: an initialised list containing 1 or more
 *                 elements.
 *   post-condition: removes and deletes the first element
 *                 and returns the remainder of the list.
 */
list tail (list l);

```

C++ definition of the list methods in a class

c++/lists/single-list/int/slist.h

```

#ifndef SLISTH
#define SLISTH

/*
 * single linked list implementation.
 */

class element
{
public:
    element *next;
    int data;
};

```

C++ definition of the list methods in a class

c++/lists/single-list/int/slist.h

```

class slist
{
    ... // missing code

public:
    ... // missing code

    slist empty (void);
    bool is_empty (void);
    slist cons (int i);
    int head (void);
    slist tail (void);
};
#endif

```

Comments on the class

- notice that because we are using a class we no longer need to pass the list as a parameter
 - it is implied by the object and reference as this
- notice that we specify which methods are visible for the user (via the keyword `public` :)

Example 1: how might this code be used?

c++/lists/single-list/int/test-slist.cc

```

/*
 * test-slist.cc - test code for the slist.cc module.
 */

#include <slist.h>
#include <cassert>

main ()
{
  {
    slist l; // created and automatically initialised
    assert (l.is_empty ());
    assert (l.empty ().is_empty ()); // recreated empty
  }
}

```

Example 2

c++/lists/single-list/int/test-slist.cc

```

{
  slist l;
  assert (l.cons (12).head () == 12);
}

```

Example 3, 4

c++/lists/single-list/int/test-slist.cc

```

{
  slist l;
  assert (l.cons (12).tail ().is_empty ());
}

```

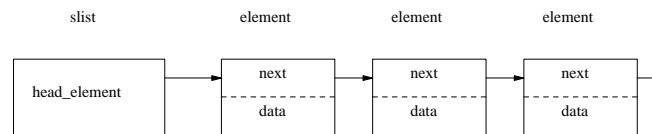
```

{
  slist l;

  l = l.cons (12);
  l = l.tail ();
  assert (l.is_empty ());
}

```

Diagram showing a possible implementation of the list



slist.h revisited

c++/lists/single-list/int/slist.h

```

#ifndef SLISTH
#define SLISTH

/*
 * single linked list implementation.
 */

class element
{
public:
    element *next;
    int data;
};

```

slist.h revisited

c++/lists/single-list/int/slist.h

```

class slist
{
private:
    element *head_element;
    element *duplicate_elements (element *e);
    element *delete_elements (element *h);

public:
    slist (void);
    ~slist (void);
    slist (const slist &from);
    slist& operator= (const slist &from);

    slist empty (void);
    bool is_empty (void);
    slist cons (int i);
    int head (void);
    slist tail (void);
};
#endif

```

slist.h revisited

- notice we introduce the `head_element` field as a private field
- we also have some private helper methods: `duplicate_elements` and `delete_elements`
- which duplicate and delete all elements

The C++ rule of three!

- most important!
- you must consider implementing : destructor, copy and assignment, methods for your class

c++/lists/single-list/int/slist.h

```

~slist (void); // destructor
slist (const slist &from); // copy
slist& operator= (const slist &from); // assignment

```

- the compiler will call these methods when evaluating expressions

The C++ rule of three!

```
static int a, b, c, t;
...
t = c * (a+b)
...
```

- notice the compiler will need to compute $a+b$ first and store this in a temporary before multiplying it by c

- in a similar way the C++ compiler will need to make temporary copies of the list when translating:

```
c++/lists/single-list/int/test-slist.cc
```

```
l.cons (12).tail ().is_empty ()
```

Output

- we can add an output method for this class overloading the traditional C++ shift operator $<<$

```
c++/lists/single-list/int/slist.h
```

```
friend std::ostream& operator<< (std::ostream& os, const
```

- check that this is inside `slist.h` and examine the implementation in `slist.cc`

slist::slist (void)

```
c++/lists/single-list/int/slist.cc
```

```
/*
 * slist - constructor, builds an empty list.
 *      pre-condition:  none.
 *      post-condition: list is created and is empty.
 */
slist::slist (void)
: head_element(0)
{
}
```

Destructor (first of the three!)

```
c++/lists/single-list/int/slist.cc
```

```
/*
 * ~slist - destructor, releases the memory attached
 *      pre-condition:  none.
 *      post-condition: list is empty.
 */
slist::~slist (void)
{
    head_element = delete_elements (head_element);
}
```

slist::delete_elements

c++/lists/single-list/int/slist.cc

```

/*
 * delete_elements - delete all elements specified by, h
 *                   pre-condition: h points to a list
 *                   post-condition: zero is returned and
 *                   elements are deleted
 */

element *slist::delete_elements (element *h)
{
    while (h != 0) {
        element *t = h;
        h = h->next;
        if (debugging)
            printf ("wanting to delete 0x%p\n", t);
        else
            delete t;
    }
    return 0;
}

```

Copy operator (second of the big three!)

c++/lists/single-list/int/slist.cc

```

/*
 * copy operator - redefine the copy operator.
 *                 pre-condition : a list.
 *                 post-condition: a copy of the list a
 */

slist::slist (const slist &from)
{
    head_element = duplicate_elements (from.head_element);
}

```

slist::duplicate_elements

c++/lists/single-list/int/slist.cc

```

/*
 * duplicate_elements - return a copy of all elements for
 *                   pre-condition: e points to a li
 *                   post-condition: a duplicate list
 */

element *slist::duplicate_elements (element *e)
{
    element *h = 0;
    element *l = 0;
    element *n;

```

slist::duplicate_elements

c++/lists/single-list/int/slist.cc

```

while (e != 0)
{
    n = new element;
    n->data = e->data;
    n->next = 0;
    if (h == 0)
        h = n;
    else
        l->next = n;
    l = n;
    e = e->next;
}
return h;
}

```

Assignment operator (3rd of the big three!)

c++/lists/single-list/int/slist.cc

```

/*
 * operator= - redefine the assignment operator.
 *             pre-condition : a list.
 *             post-condition: a copy of the list and
 *                             We delete 'this' lists
 */

slist& slist::operator= (const slist &from)
{
    head_element = delete_elements (head_element);
    head_element = duplicate_elements (from.head_element);
}

```

slist::empty

c++/lists/single-list/int/slist.cc

```

/*
 * empty - returns a new empty list.
 *         pre-condition: none.
 *         post-condition: a new empty list is returned
 */

slist slist::empty (void)
{
    slist *l = new slist;
    return *l;
}

```

slist::is_empty

c++/lists/single-list/int/slist.cc

```

/*
 * is_empty - returns true if list is empty.
 */

bool slist::is_empty (void)
{
    return head_element == 0;
}

```

slist::cons (int i)

c++/lists/single-list/int/slist.cc

```

/*
 * cons - concatenate i to slist.
 *        pre-condition: none.
 *        post-condition: returns the list which has i
 *                        and the remainder of contents
 */

slist slist::cons (int i)
{
    element *e = new element;

    e->data = i;
    e->next = head_element;
    head_element = e;
    return *this;
}

```

slist::head

c++/lists/single-list/int/slist.cc

```

/*
 * head - returns the data at the front of the list.
 *       pre-condition : slist is not empty.
 *       post-condition: data at the front of the list
 *
 */

int slist::head (void)
{
    assert (! is_empty());
    return head_element->data;
}

```

slist::tail

c++/lists/single-list/int/slist.cc

```

/*
 * tail - opposite of cons. Remove the head value and r
 *       the remainder of the list.
 *       pre-condition: non empty list.
 *       post-condition: return the list without the f
 */

slist slist::tail (void)
{
    element *e = head_element;

    assert (! is_empty());
    head_element = head_element->next;
    if (debugging)
        printf ("wanting to delete 0x%p\n", e);
    else
        delete e;
    return *this;
}

```

Tutorial Questions

- check out the example code

```

$ git clone https://github.com/gaiusm/examples
$ cd examples/c++/lists/single-list/int
$ make

```

- now single step the a.out executable using using gdb
 - satisfy your self that the big three are being invoked (copy, assignment and destructor methods)

Tutorial Questions

- implement the method
 - int length (void); and add this to the class slist
 - length returns the number of elements in slist
 - write some test code for length
- implement the method
 - slist cons (slist l);
 - this method must concatenate the contents of list, l, onto this
 - take case as l might be the same as this
- implement the method
 - slist reverse (void);

Tutorial Questions

- implement

- ```
/*
 * slice - return a slice of the list.
 * pre-condition: an initialised non empty list
 * post-condition: the original list is unaltered
 * A new list is returned which
 * a copy of elements, l..r-1
 * Negative values of l and r
 * index from the right (aka Python)
 */
slist slist::slice (int l, int r);
```