COMP1917: Computing 1

14. Linked Lists

Reading: Moffat, Section 10.1-10.2

Overview

- Self-referential structures
- Linked Lists
- List operations
- Stacks
- Ordered lists

Self-Referential Structures

We can define a structure containing within it a pointer to the same type of structure:

```
typedef struct lnode Lnode;

struct lnode {
    int    data;
    Lnode *next;
};
```

These “self-referential” pointers can be used to build larger “dynamic” data structures out of smaller building blocks.

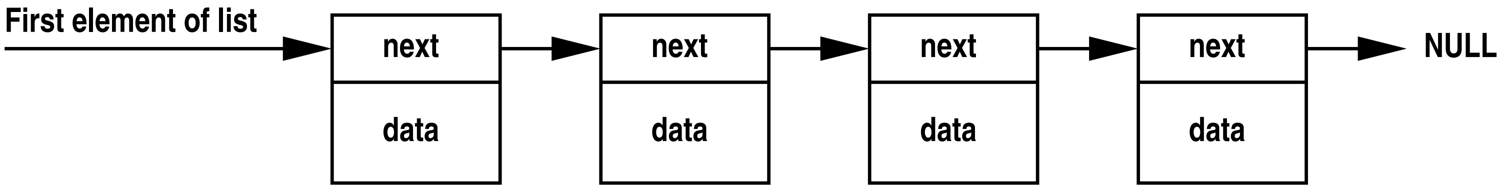
Linked Lists

The most fundamental of these dynamic data structures is the Linked List:

- based on the idea of a sequence of data items or nodes
- linked lists are more flexible than arrays:
  - items don't have to be located next to each other in memory
  - items can easily be rearranged by altering pointers
  - the number of items can change dynamically
  - items can be added or removed in any order

We will look at how to create lists and some useful operations for manipulating them.

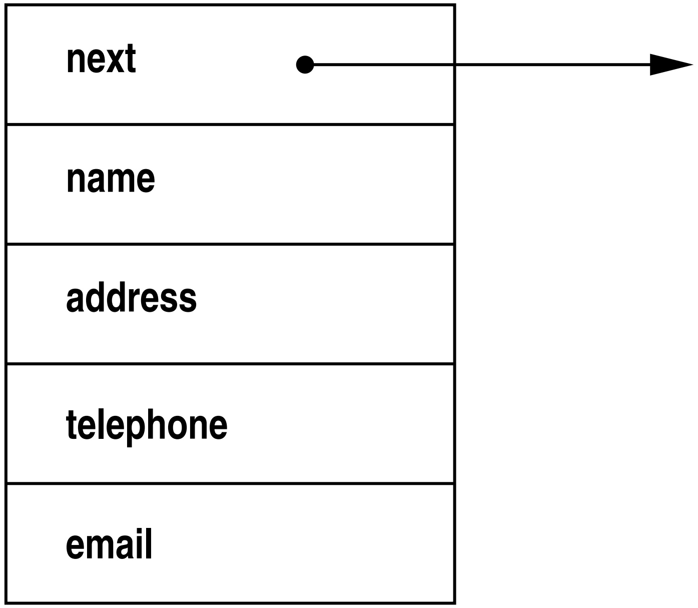
Linked List



- a linked list is a sequence of items
- each items of the list contains data and a pointer to the next item
- also need to maintain a pointer to the first item or “head” of the list
- the last item in the list points to `NULL`
- need to distinguish between the node and the data;
  the node is like a “container” which holds the data inside it.

Linked List Node

Example of a list node:



Linked List Node Structure in C

```
typedef struct addressNode AddressNode;

    struct addressNode {
        AddressNode *next;
        char *name;
        char *address;
        char *telephone;
        char *email;
    };
```

List Operations

Fundamental List operations:

- create a new node with specified data
- search for a node with particular data
- insert a new node to the list
- remove a node from the list

Other operations are possible and can be added as needed.

Lists also form the basis for useful data structures like stacks and queues.

List Operations

```
Lnode * makeNode( int data );      // create new node

Lnode * findNode( int data, Lnode *head );

Lnode * push( Lnode *new_node, Lnode *head );// to front
Lnode * pop ( Lnode *head );       // first item

void    printList( Lnode *head ); // print all items
void    freeList ( Lnode *head ); // clear entire list

Lnode * insert( Lnode *new_node, Lnode *head );// in order
Lnode * excise( Lnode *old_node, Lnode *head );
```

Making a New Node

```
/*
   Create a new node containing the specified data,
   and return a pointer to this newly-created node.
*/
Lnode * makeNode( int data )
{
   Lnode *new_node =(Lnode *)malloc( sizeof( Lnode ));
   if( new_node == NULL ) {
       fprintf(stderr,"Error: memory allocation failed.\n");
       exit( 1 );
   }
   new_node->data = data;
   new_node->next = NULL;
   return( new_node );
}
```

Finding a Node in a List

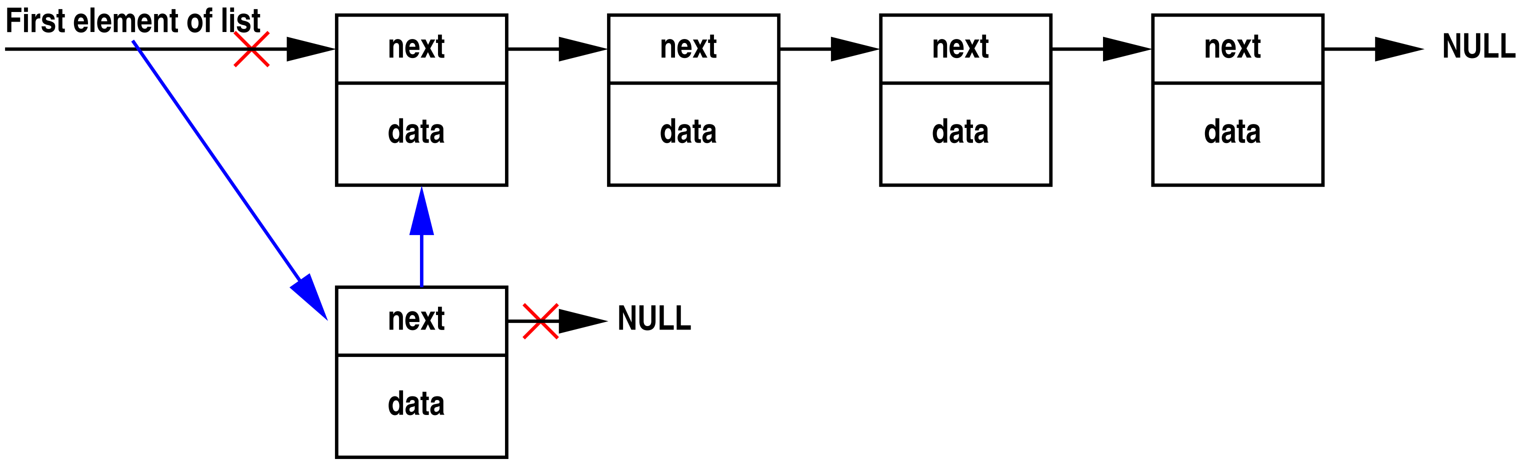
```
/*
   Search through list to find the first node with the
   specified data, and return a pointer to this node.
   If no such node exists, return NULL.
*/
Lnode * findNode( int data, Lnode *head )
{
   Lnode *node = head; // start at first node in list

   // keep searching until data found, or end of list
   while(( node != NULL )&&( node->data != data )) {
       node = node->next;
   }
   return( node );
}
```


Recursive version of `findNode()`

```
/*
   First check the head. Then check the rest, which is also
   a list, by making the function (recursively) call itself!
*/
Lnode * findNode( int data, Lnode *head )
{
   if(( head == NULL )||( head->data == data )) {
       return( head );
   }
   else {
       return( findNode( data, head->next ));
   }
}
```

Question: Could this function keep calling itself, to infinity? Why not?

Push a Node onto the Front of a List



Pushing a new item involves two operations:

- make the new node point to the current head of the list
- make the new node become the new head of the list

Push a Node onto the Front of a List

```
/*
   Push new node to front of list and
   return the resulting (longer) list
*/
Lnode * push( Lnode *new_node, Lnode *head )
{
   new_node->next = head;
   return( new_node );
}
```

Since this function returns the new list, it should be called like this:

```
list = push( makeNode('A'), list );
```

Pop the First Node from a List

```
/*
   Pop first item from list and
   return the remaining (shorter) list
*/
Lnode * pop( Lnode *head )
{
    Lnode *tmp = head;

    if( head != NULL ) {
        head = head->next;
        free( tmp );
    }
    return( head );
}
```

Printing a List

```
/*
   Print all items in the list one by one
*/
void printList( Lnode *head )
{
   Lnode *node = head;

   // traverse the list printing each node in turn
   while( node != NULL ) {
       printf( "->%c", node->data );
       node = node->next;
   }
   printf( "\n" );
}
```

Recursive version of `printList()`

```
/*
   First print the head, then print the rest, which is also
   a list, by having the function (recursively) call itself
*/
void printList( Lnode *head )
{
   if( head != NULL ) { // avoid "infinite descent"
       printf( "->%c", head->data );
       printList( head->next );
   }
   else {
       printf( "\n" );
   }
}
```

Deleting all items from a List

```
/*
   Delete all the items from a linked list.
*/
void freeList( Lnode *head )
{
    Lnode *node = head;
    Lnode *tmp;

    while( node != NULL ) {
        tmp = node;
        node = node->next;
        free( tmp );
    }
}
```

Example: `stack.c`

```
int main( void )
{
   Lnode *list = NULL;
   int ch;

   while(( ch = getchar()) != EOF ) {
      if ( ch == '-' )
          list = pop( list );
      else if( ch == '\n' )
          printList( list );
      else
          list = push( makeNode(ch), list );
   }
   freeList( list );
}
```

Insert a Node into an Ordered List

```
Lnode * insert( Lnode *new_node, Lnode *head )
{
   Lnode *next_node = head;
   while(  new_node->data > next_node->data ) {

       next_node = next_node->next; // find correct position
   }



                                            // link new node into list

   new_node->next = next_node;
   return( head );
}
```

Problem: need to keep track of previous node!

insert() - version 2

```
Lnode * insert( Lnode *new_node, Lnode *head )
{
   Lnode *next_node = head, *prev_node;
   while(  new_node->data > next_node->data ) {
       prev_node = next_node;
       next_node = next_node->next; // find correct position
   }




       prev_node->next = new_node;  // link new node into list

   new_node->next = next_node;
   return( head );
}
```

Problem: what if new node goes at the end?

insert() - version 3

```
Lnode * insert( Lnode *new_node, Lnode *head )
{
   Lnode *next_node = head, *prev_node;
   while( next_node && new_node->data > next_node->data) {
       prev_node = next_node;
       next_node = next_node->next; // find correct position
   }



       prev_node->next = new_node;  // link new node into list

   new_node->next = next_node;
   return( head );
}
```

Problem: what if new node goes at the beginning?

insert() - final version

```
Lnode * insert( Lnode *new_node, Lnode *head )
{
   Lnode *next_node = head, *prev_node = NULL;
   while( next_node && new_node->data > next_node->data) {
       prev_node = next_node;
       next_node = next_node->next; // find correct position
   }
   if( prev_node == NULL )
       head = new_node;
   else {
       prev_node->next = new_node;  // link new node into list
   }
   new_node->next = next_node;
   return( head );
}
```

Exercise: check this works in all cases.

Remove a Node from a List

```
Lnode * excise( Lnode *node, Lnode *head )
{
   if( node != NULL ) {
       if( node == head )
           head = head->next;          // remove first item
       else {
           Lnode *prev_node = head;
           while( prev_node && prev_node->next != node ) {
               prev_node = prev_node->next;
           }
           if( prev_node != NULL ) { // node found in list
               prev_node->next = node->next;
           }
       }
   }
   return( head );
}
```


Exercise

Check that `excise()` behaves sensibly in all of these cases:

- removing first item
- removing last item
- removing interior item
- `node` is not in list
- `node` is `NULL`
- list is empty
- `node` is `NULL` AND list is empty.

Example: `ordered.c`

```
int main( void )
{
   Lnode *list = NULL;
   Lnode *node;
   int  ch;

   while(( ch = getchar()) != EOF ) {
      if ( ch == '-' ) { // remove item from list
          ch = getchar();
          node = findNode( ch, list );
          if( node != NULL ) {
              list = excise( node, list );
              free( node );
          }
      }
```

Example: `ordered.c` cont'd

```
 ...
      else if( ch == '\n' ) {
          printList( list );
      }
      else {
          list = insert( makeNode(ch), list );
      }
   }
   freeList( list );

   return 0;
}
```

