COMP1917: Computing 1

15. Stacks and Queues

Reading: Moffat, Section 10.1-10.2

Overview

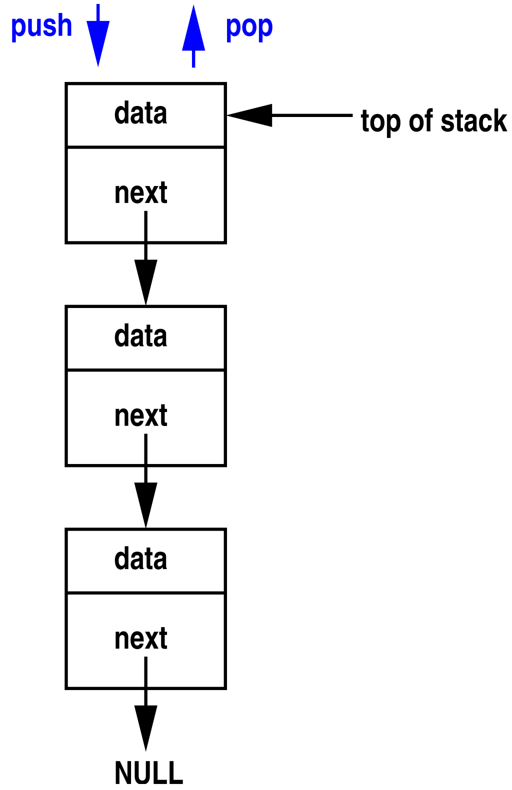
- Stacks
- Queues
- Adding to the Tail of a List
- Efficiency Issues
- Queue Structure
- Stack Application: Postfix Calculator

Stacks and Queues

- Stacks and Queues are examples of Abstract Data Types
- Stacks and Queues are used in many computing applications,
  as well as forming auxiliary data structures for common algorithms,
  and appearing as components of larger structures.

Stacks

- a stack is a collection of items such that the last item to enter is the first one to exit, i.e. "last in, first out" (LIFO)
- based on the idea of a stack of books, or plates



Stack Functions

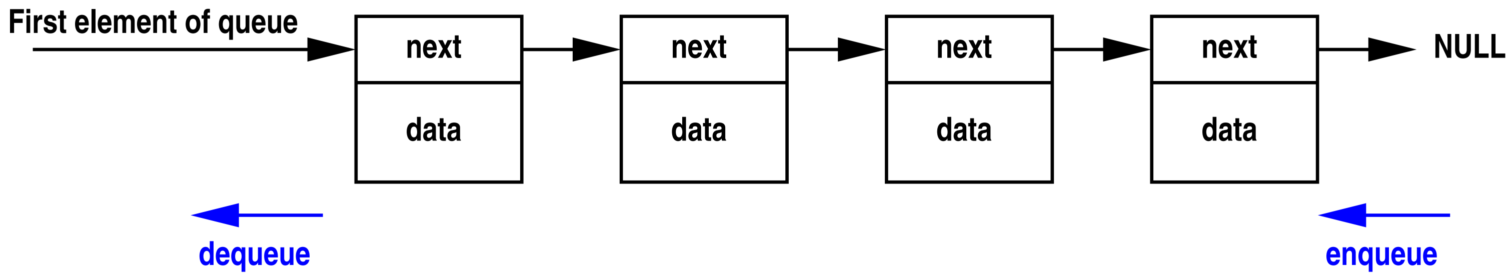
- Essential Stack functions:
  - `push() // add new item to stack`
  - `pop() // remove top item from stack`
- Additional Stack functions:
  - `top() // fetch top item (but don't remove it)`
  - `size() // number of items`
  - `isEmpty()`

Stack Applications

- page-visited history in a Web browser
- undo sequence in a text editor
- checking for balanced brackets
- HTML tag matching
- postfix calculator
- chain of function calls in a program

Queues

- a queue is a collection of items such that the first item to enter is the first one to exit, i.e. “first in, first out” (FIFO)
- based on the idea of queueing at a bank, shop, etc.



Queue Functions

- Essential Queue functions:
  - `enqueue() // add new item to queue`
  - `dequeue() // remove front item from queue`
- Additional Queue functions:
  - `front() // fetch front item (but don't remove it)`
  - `size() // number of items`
  - `isEmpty()`

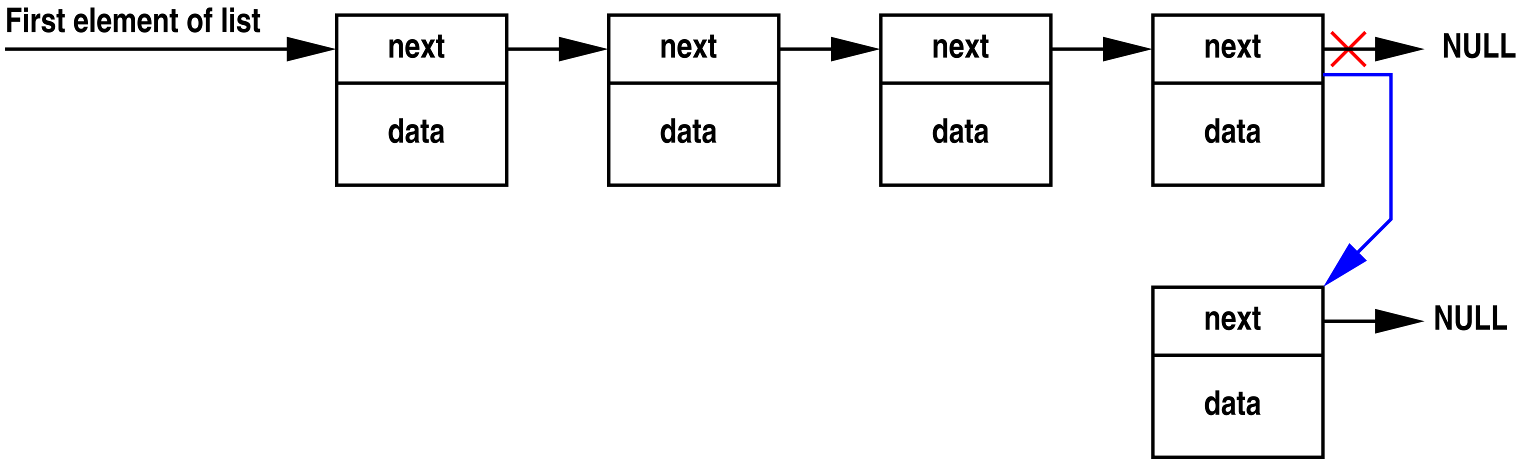
Queue Applications

- waiting lists, bureaucracy
- access to shared resources (printers, etc.)
- phone call centres
- multiple processes in a computer

Implementing Stacks and Queues

- a stack can be implemented using a linked list, by adding and removing at the head [`push()` and `pop()`]
- for a queue, we need to either add or remove at the tail
  - can either of these be done efficiently?

Adding to the Tail of a List



- adding an item at the tail is achieved by making the last node of the list point to the new node
- we first need to scan along the list to find the last item

Adding to the Tail of a List

```
Lnode * add_to_tail( Lnode *new_node, Lnode *head )
{
   if( head == NULL ) {       // list is empty
       head = new_node;
   }
   else {                     // list not empty
       Lnode *node = head;
       while( node->next != NULL ) {
           node = node->next; // scan to end
       }
       node->next = new_node;
   }
   return( head );
}
```

Efficiency Issues

Unfortunately, this implementation is very slow. Every time a new item is inserted, we need to traverse the entire list (which could be very large).

We can do the job much more efficiently if we retain a direct link to the last item or "tail" of the list:

```
if( tail == NULL ) { // list is empty
    head = node;
}
else {               // list not empty
    tail->next = node;
}
tail = node;
```

Note: there is no way to efficiently remove items from the tail. (Why?)

Queue Structure

We can use this structure to implement a queue efficiently:

```
typedef struct queue Queue;

struct queue {
    Lnode *head;
    Lnode *tail;
    int size;
};
```

Making a new Queue

```
Queue * makeQueue()
{
   Queue *q = (Queue *)malloc( sizeof( Queue ));
   if( q == NULL ) {
      fprintf(stderr,"Error, failed to allocate Queue.\n");
      exit( 1 );
   }
   q->head = NULL;
   q->tail = NULL;
   q->size = 0;

   return( q );
}
```

Adding a new Item to a Queue

```
void enqueue( Lnode *new_node, Queue *q )
{
   if( q->tail == NULL ) { // queue is empty
       q->head = new_node;
   }
   else {                  // queue not empty
       q->tail->next = new_node;
   }
   q->tail = new_node;
   q->size++;
}
```

Removing an Item from a Queue

```
Lnode * dequeue( Queue *q )
{
   Lnode *node = q->head;

   if( q->head != NULL ) {
       if( q->head == q->tail ) { // only one item
           q->tail = NULL;
       }
       q->head = q->head->next;

       q->size--;
   }
   return( node );
}
```

Example: `queue.c`

```
int main( void )
{
   Queue *q = makeQueue();
   Lnode *node;
   int  ch;

   while(( ch = getchar()) != EOF ) {
      if( ch == '-' ) {
          node = dequeue( q );
          if( node != NULL ) {
              printf("Dequeueing %c\n", node->data );
              free( node );
          }
      }
```

Example: queue.c

```
 ...
      else if( ch == '\n' ) {
          printList( q->head );
      }
      else {
          enqueue( makeNode(ch), q );
      }
   }
   freeList( q->head );

   return 0;
}
```

Reverse Polish Notation

Some early calculators and programming languages used a convention known as Reverse Polish Notation (RPN) where the operator comes after the two operands rather than between them:

```
1 2 +
result = 3
3 2 *
result = 6
4 3 + 6 *
result = 42
1 2 3 4 + * +
result = 15
```


Postfix Calculator

A calculator using RPN is called a Postfix Calculator; it can be implemented using a stack:

- when a number is entered: push it onto the stack
- when an operator is entered: pop the top two items from the stack, apply the operator to them, and push the result back onto the stack.

postfix.c

```
int main( void )
{
  Lnode *list = NULL;
  int num;
  int a,b, num;

  while(( ch = getc(stdin)) != EOF ) {
     if( ch == '\n' ) {
         printf("Result: %d\n", list->data );
     }
     else if( isdigit(ch)) {
         ungetc( ch, stdin );  // put first digit back to file
         scanf( "%d", &num );  // now scan entire number
         list = push( makeNode(num), list );
     }
```

postfix.c

```
else if( ch == '+' || ch == '-' || ch == '*' ) {
    if( list != NULL ) {
        a = list->data;       // fetch top item
        list = pop( list );
        if( list != NULL ) {
            b = list->data;   // fetch 2nd item
            list = pop( list );
            switch( ch ) {
              case '+':  num = b + a;  break;
              case '-':  num = b - a;  break;
              case '*':  num = b * a;  break;
            }
            list = push( makeNode(num), list );
        }
    }
}
}
```