# COMP1511: Abstract Data Types, Stacks and Queues

Session 2, 2018

# Abstract Data Types

A ***data type*** is ...

- a set of values (atomic or structured values)
- a collection of operations on those values

An ***abstract data type*** is ...

- an approach to implementing data types
- ***separates*** *interface* from *implementation*
- users of the ADT see only the interface
- builders of the ADT provide an implementation

*For example*, do you know what a (`FILE *`) looks like? do you want/need to know how it is implemented? Not really!

# Interface vs Implementation

ADT ***interface*** provides

- a user-view of the data structure (e.g. FILE*)
- function signatures (prototypes) for all operations
- semantics of operations (via documentation)
- a contract between ADT and its clients

ADT ***implementation*** gives

- concrete definition of the data structures
- definition of functions for all operations

# Stacks and Queues

- Stacks and queues ubiquitous data-structure in computing.
- Part of many important algorithms .
- Good example of abstract data types.
- Good example to practice programming with arrays
- Good example to practice programming with linked lists

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# Stack - Abstract Data Type

- a *stack* is a collection of items such that the *last* item to enter is the *first* one to exit
- "last in, first out" (LIFO)
- based on the idea of a stack of books, or plates
- essential Stack operations:
  - `push() // add new item to stack`
  - `pop() // remove top item from stack`
- additional Stack operations:
  - `top() // fetch top item (but don't remove it)`
  - `size() // number of items`
  - `is_empty()`

# Stack Applications

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

# Stack - Abstract Data Type - C Interface

```c
typedef struct stack_internals *stack;
stack stack_create(void);
void stack_free(stack stack);
void stack_push(stack stack, int item);
int stack_pop(stack stack);
int stack_is_empty(stack stack);
int stack_top(stack stack);
int stack_size(stack stack);
```

# Stack - Abstract Data Type - using C Interface

```
stack s;
s = stack_create();
stack_push(s, 10);
stack_push(s, 11);
stack_push(s, 12);
printf("%d\n", stack_size(s)); // prints 3
printf("%d\n", stack_top(s)); // prints 12
printf("%d\n", stack_pop(s)); // prints 12
printf("%d\n", stack_pop(s)); // prints 11
printf("%d\n", stack_pop(s)); // prints 10
```

- Implementation of stack is **opaque** (hidden from user).
- User programs can not depend on how stack is implementated.
- Stack implementation can change without risk of breaking user programs.
- This type of **information hiding** is crucial to managing complexity in large software systems.

# Queue Abstract Data Type

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

# Queue Applications

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

# Queue - Abstract Data Type - C Interface

```
queue queue_create(void);
void queue_free(queue queue);
void queue_enqueue(queue queue, int item);
int queue_dequeue(queue queue);
int queue_is_empty(queue queue);
int queue_front(queue queue);
int queue_size(queue queue);
```

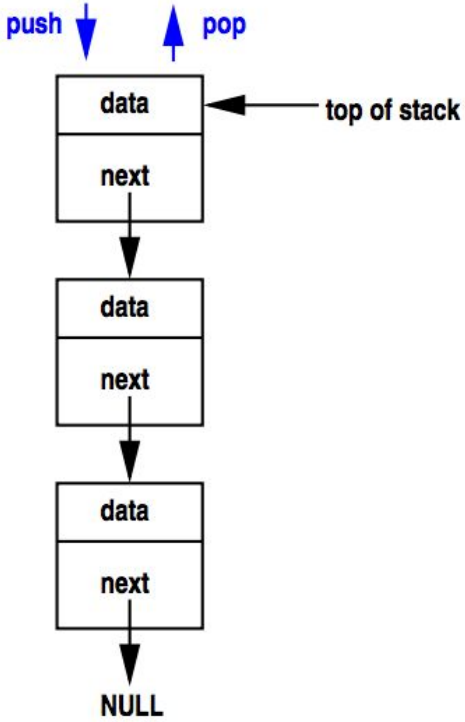
# Queue - Abstract Data Type - C Interface

```
queue q;
q = queue_create();
queue_enqueue(q, 10);
queue_enqueue(q, 11);
queue_enqueue(q, 12);
printf("%d\n", queue_size(q)); // prints 3
printf("%d\n", queue_front(q)); // prints 10
printf("%d\n", queue_dequeue(q)); // prints 10
printf("%d\n", queue_dequeue(q)); // prints 11
printf("%d\n", queue_dequeue(q)); // prints 12
```

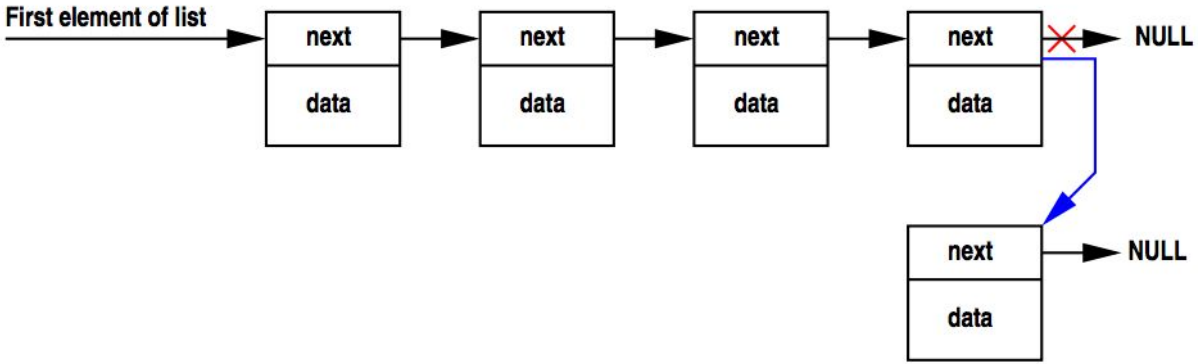
- Again implementation of queue is **opaque**.
- Queue implementation can change **without** risk of breaking user programs

# Implementing A Stack with a Linked List

- 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 - (Append?)

```
struct node *add_to_tail( *new_node, struct node *he
    if (head == NULL) {          // list is empty
        head = new_node;
    } else {                     // list not empty
        struct node *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).

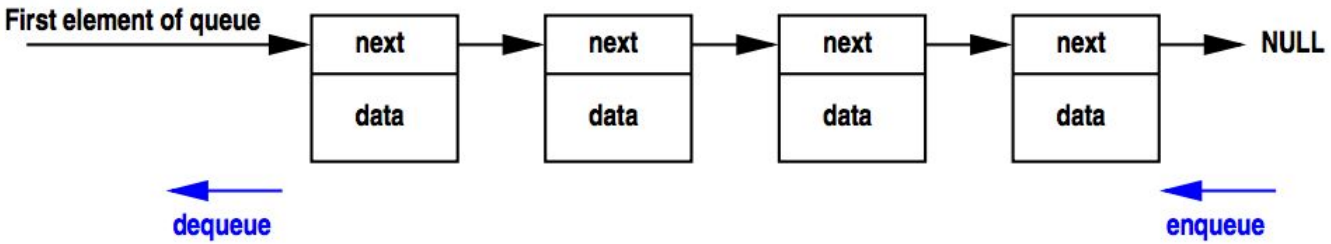
We can do the job much more efficiently if we retain a direct link to the last item or "tail" of the list:

```
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?)

# Queues Implementation

- 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.



# 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

```c
#include <stdio.h>
#include <ctype.h>
#include "stack.h"

int main(void) {
  int ch;

  stack s = stack_create();

  while ((ch = getc(stdin)) != EOF) {
    if (ch == '\n') {
      printf("Result: %d\n", stack_pop(s));
    } else if (isdigit(ch)) {
      ungetc(ch, stdin);  // put first digit back
      int num;
      scanf("%d", &num);  // now scan entire number
      stack_push(s, num);
```

# postfix.c

```
    } else if (ch == '+' || ch == '-' || ch == '*') {
      int a = stack_pop(s);
      int b = stack_pop(s);
      int result;
      if (ch == '+') {
        result = b + a;
      } else if (ch == '-') {
        result = b - a;
      } else {
        result = b * a;
      }
      stack_push(s, result);
    }
  }
}
```