Review of Data Structures

- We’ve studied concrete data structures/type (CDT)
  - Vectors
    - Homogeneous aggregates supporting random access
  - Linked lists
    - Collections supporting constant-time insertion

- We’ve studied sets of strings as an abstraction with different concrete implementations (readset.cpp, readset2.cpp, ...)
  - Sorted vectors, linked list, many linked lists, search trees
  - Different concrete implementations had different performance characteristics, but the client code did NOT change!

- We studied the concrete implementations to understand efficiency
  - Abstractly, what are operations performed on set?
  - Need to view data abstractly, easier to be a client
Stack: What problems does it solve?

- Stacks are used to avoid recursion, a stack can replace the implicit/actual stack of functions called recursively

- Stacks are used to evaluate arithmetic expressions, to implement compilers, to implement interpreters
  - The Java Virtual Machine (JVM) is a stack-based machine
  - Postscript is a stack-based language
  - Stacks are used to evaluate arithmetic expressions in many languages

- Small set of operations: LIFO or last in is first out access
  - Operations: push, pop, top, create, clear, size
  - More in postscript, e.g., swap, dup, rotate, ...
Simple stack example

- **tstack** is a templated class, stores any type of value that can be assigned (like tvector)
  - Implemented simply using a vector, what does pop do?

```cpp
tstack<int> s;
s.push(2);
s.push(3);
s.push(1);
cout << s.size() << endl;
cout << s.top() << endl;
s.pop();
cout << s.top() << endl;
int val;
s.pop(val);
cout << val << endl;
```
Templated class, .h ok, .cpp ugly

- See tstack.h for example

```cpp
template <class Type>
class tstack
{
    public:
        tstack( );                   // construct empty stack
        const Type & top( ) const;   // return top element
        bool  isEmpty( ) const;     // return true iff empty
        int   size( ) const;        // # elements

        void push( const Type & item ); // push item
}
```

- But look at part of stack.cpp, class is templated (ugly?)

```cpp
template <class Type>
bool tstack<Type>::isEmpty() const
{
    return myElements.size() == 0;
}
```
Template class: implementation notes

- A templated function or class isn’t code, per se, but template (or pattern) for generating the “real” code
  - The templated class or function is instantiated when an object is created, or a function called
  - The template code is instantiated for a particular type
    - tvector<int> a; // creates code int vector
    - QuickSort(a, a.size()); // create function

- Since not really code, header declaration needs access to .cpp implementation at compile time
  - Typically use #include “foo.cpp” in foo.h, then client code gets both .h and .cpp
  - Ok because not code, otherwise would cause problems at link time with duplicate function/class definitions
Postfix, prefix, and infix notation

- **Postfix notation used in some HP calculators**
  - No parentheses needed, precedence rules still respected
    \[ 3 \ 5 \ + \ 4 \ 2 \ * \ 7 \ + \ 3 \ - \ 9 \ 7 \ + \ * \]
  - Read expression
    - For number/operand: push
    - For operator: pop, pop, operate, push

- **See postfix.cpp for example code, key ideas:**
  - Read character by character, check state of expression
  - Note: putback character on stream, only last one read

- What about prefix and infix notations, advantages?
Prefix notation in action

- Scheme/LISP and other functional languages tend to use a prefix notation

$(\text{define} \ (\text{square} \ x) \ (\ast \ x \ x))$

$(\text{define} \ (\text{expt} \ b \ n) \n  \ (\text{if} \ (= \ n \ 0) \n    1 
    (* \ b \ (\text{expt} \ b \ (- \ n \ 1)))))$
Postfix notation in action

- Practical example of use of stack abstraction
- Put operator after operands in expression
  - Use stack to evaluate
    - operand: push onto stack
    - operator: pop operands push result
- PostScript is a stack language mostly used for printing
  - drawing an X with two equivalent sets of code

```plaintext
%!  
200 200 moveto  
100 100 rlineto  
200 300 moveto  
100 -100 rlineto  
stroke showpage
```
Queue: another linear ADT

- **FIFO: first in, first out, used in many applications**
  - Scheduling jobs/processes on a computer
  - Tenting policy?
  - Computer simulations

- **Common operations (as used in tqueue.h/tqueue.cpp)**
  - Add to back, remove from front
    - Called enqueue, dequeue, like s.push() and s.pop()
    - Analog of top() is front()
  - Also used in level-order tree traversal, similar to pre-order without recursion but using stack
    - See code in treelevel.cpp
Stack and Queue implementations

- Different implementations of queue (and stack) aren’t really interesting from an algorithmic standpoint
  - Complexity is the same, performance may change (why?)
  - Use vector or linked list, any sequential structure

- Linked list is easy for stack, where to add/remove nodes?

- Linked list is easy for queue, where to add/remove nodes?
  - Use circular linked list, why?

- Vector for queue is tricky, need ring buffer implementation, add but wrap-around if possible before growing
  - Tricky to get right (see tqueue.h, tqueue.cpp)
Using linear data structures

- We’ve studied vectors, stacks, queues, which to use?
  - It depends on the application
  - Vector is multipurpose, why not always use it?
    - Make it clear to programmer what’s being done
    - Other reasons?

- Other linear ADTs exist
  - List: add-to-front, add-to-back, insert anywhere, iterate
    - Alternative: create, head, tail (see CList<> in tapestry)
    - Linked-list nodes are concrete implementation
  - Deque: add-to-front, add-to-back, random access
    - Why is this “better” than a vector?
    - How to implement?
James Gosling

- “Invented” Java
  - First developer, originator,
- Impetus for GPL, free software?
  - Stallman writes emacs, gosling writes C version, shares it, sells it, oops trouble with shared

Stallman: “Then he stabbed everyone in the back by putting copyrights on it, making people promise not to redistribute it and then selling it to a software-house. My later dealings with him personally showed that he was every bit as cowardly and despicable as you would expect from that history.”