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
#include <tstack.h>
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
      int size() const; // # elements
      void push(const Type & item); // push item

    protected:
      std::vector<Type> myElements;
      std::size_t size;

  private:
    std::size_t index;
};
```
- 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

```
(define (square x) (* x x))
```

```
(define (expt b n)
  (if (= n 0)
    1
    (* b (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

```
%! 200 200 moveto
100 100 rlineto
200 300 moveto
100 -100 rlineto
stroke showpage
```

```
%! 100 -100 200 300 100 100 200 200
moveto rlineto moveto 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 queue.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 queue.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 C list< ... > 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.”