CSCI 136
Data Structures & Advanced Programming

Lecture 13

Fall 2019

Instructors: B&S

Announcements

Exams

- Mid-term exam is Wednesday, October 16
  - During your normal lab session
  - You'll have approximately 1 hour & 45 minutes (if you come on time!)
  - Closed-book: Covers Chapters 1-7 & 9, handouts, and all topics up through Linked Lists
- Final Exam
  - Monday, Dec. 16: 9:30 - noon (location TBA)
  - Closed-book: Comprehensive, but focused on material not covered on mid-term
  - Make travel plans accordingly!

Last Time

- Implementing Lists with linked structures
  - Singly Linked Lists
  - Circularly Linked Lists
  - Intro to Doubly-Linked Lists

Today

- Implementation of Doubly Linked Lists
  - From Lecture 12 slide deck….
- The structure5 hierarchy so far
- The Linear Interface
- Linear Structures: Stacks & Queues
- Stack Methods and Applications
  - Expressions

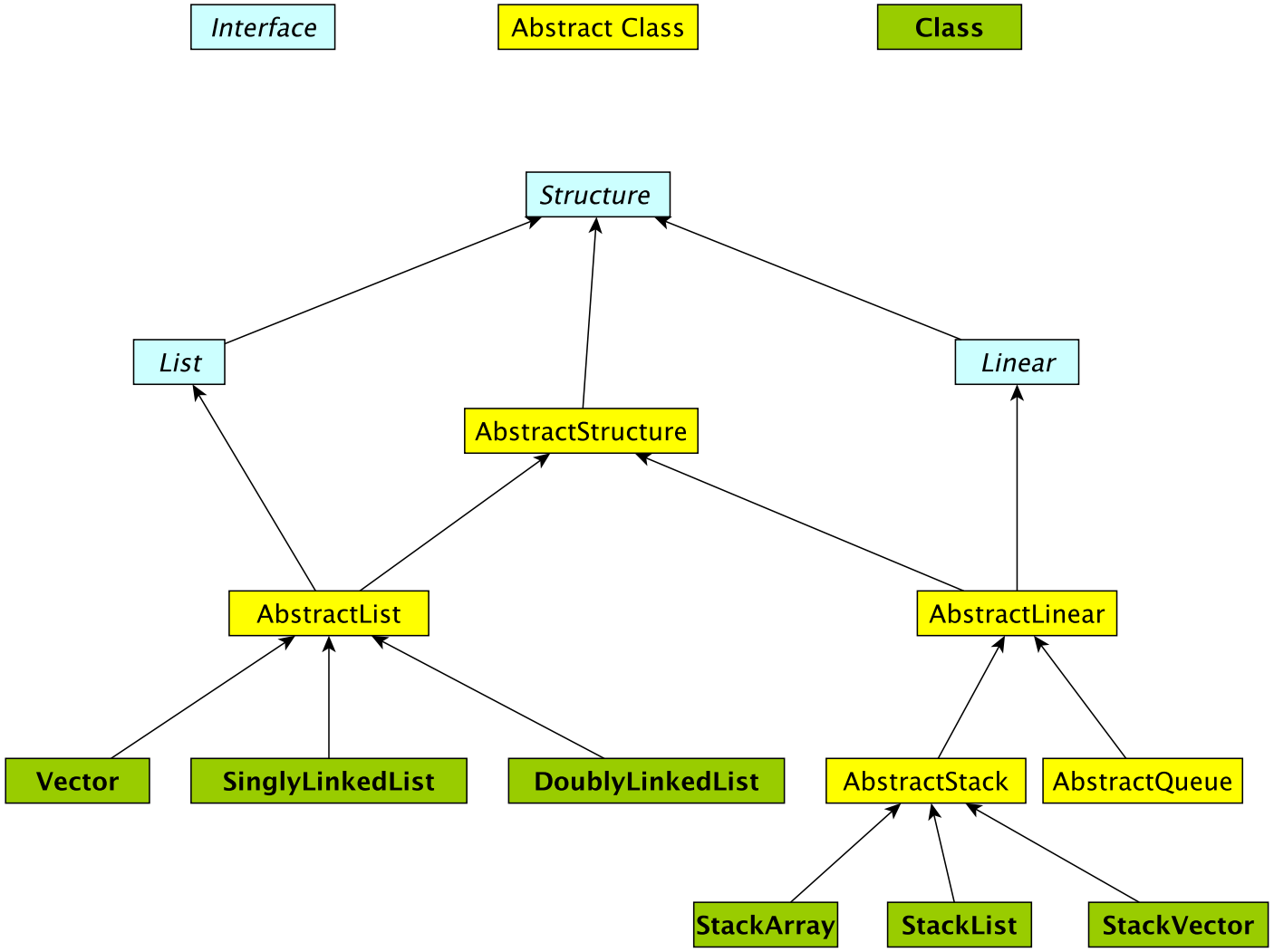
Linear Structures

- What if we want to impose *access restrictions* on our lists?
  - I.e., provide only one way to add and remove elements from list
  - No longer provide access to middle
- Key Examples: Order of removal depends on order elements were added
  - LIFO: Last In First Out
  - FIFO: First In First Out

Examples

- FIFO: First In – First Out (Queue)
  - Line at dining hall
  - Data packets arriving at a router
- LIFO: Last In – First Out (Stack)
  - Stack of trays at dining hall
  - Java Virtual Machine stack

The Structure5 Universe (next)



Linear Interface

- How should it differ from List interface?
  - Should have fewer methods than List interface since we are limiting access …
- Methods:
  - Inherits all of the Structure interface methods
    - add(E value) – Add a value to the structure.
    - E remove(E o) – Remove value o from the structure.
      - But this is awkward---why?
    - int size(), isEmpty(), clear(), contains(E value), …
  - Adds
    - E get() – Preview the next object to be removed.
    - E remove() – Remove the *next* value from the structure.
    - boolean empty() – same as isEmpty()

Linear Structures

- Why no "random access"?
  - I.e., no access to middle of list
- More restrictive than general List structures
  - Less functionality can result in
    - Simpler implementation
    - Greater efficiency
- Approaches
  - Use existing structures (Vector, LL), or
  - Use underlying organization, but simplified

Stacks

- Examples: stack of trays or cups
  - Can only take tray/cup from top of stack
- What methods do we need to define?
  - Stack interface methods
- New terms: push, pop, peek
  - Convention: Use push, pop, peek when talking about stacks
  - Push = add to top of stack
  - Pop = remove from top of stack
  - Peek = look at top of stack (do not remove)

Notes about Terminology

- When using stacks:
  - pop = remove
  - push = add
  - peek = get
- In Stack interface, pop/push/peek methods call add/remove/get methods that are declared in Linear interface
- But "add" is not mentioned in Stack interface (it is inherited from Linear)
- Stack interface **extends** Linear interface
  - Interfaces *extend* other interfaces
  - Classes *implement* interfaces

Stack Implementations

- Array-based stack
  - int top, Object data[ ]
  - Add/remove from index top

  \+ all operations are O(1)

  – wasted/run out of space

- Vector-based stack
  - Vector data
  - Add/remove from tail

  +/– most ops are O(1) (add is O(n) in worst case)

  – potentially wasted space

- List-based stack
  - SLL data
  - Add/remove from *head*

  \+ all operations are O(1)

  +/– O(n) space overhead (no "wasted" space)

Stack Implementations

- structure5.StackArray
  - int top, Object data[ ]
  - Add/remove from index top

  \+ all operations are O(1)

  – wasted/run out of space

- structure5.StackVector
  - Vector data
  - Add/remove from tail

  +/– most ops are O(1) (add is O(n) in worst case)

  – potentially wasted space

- structure5.StackList
  - SLL data
  - Add/remove from head

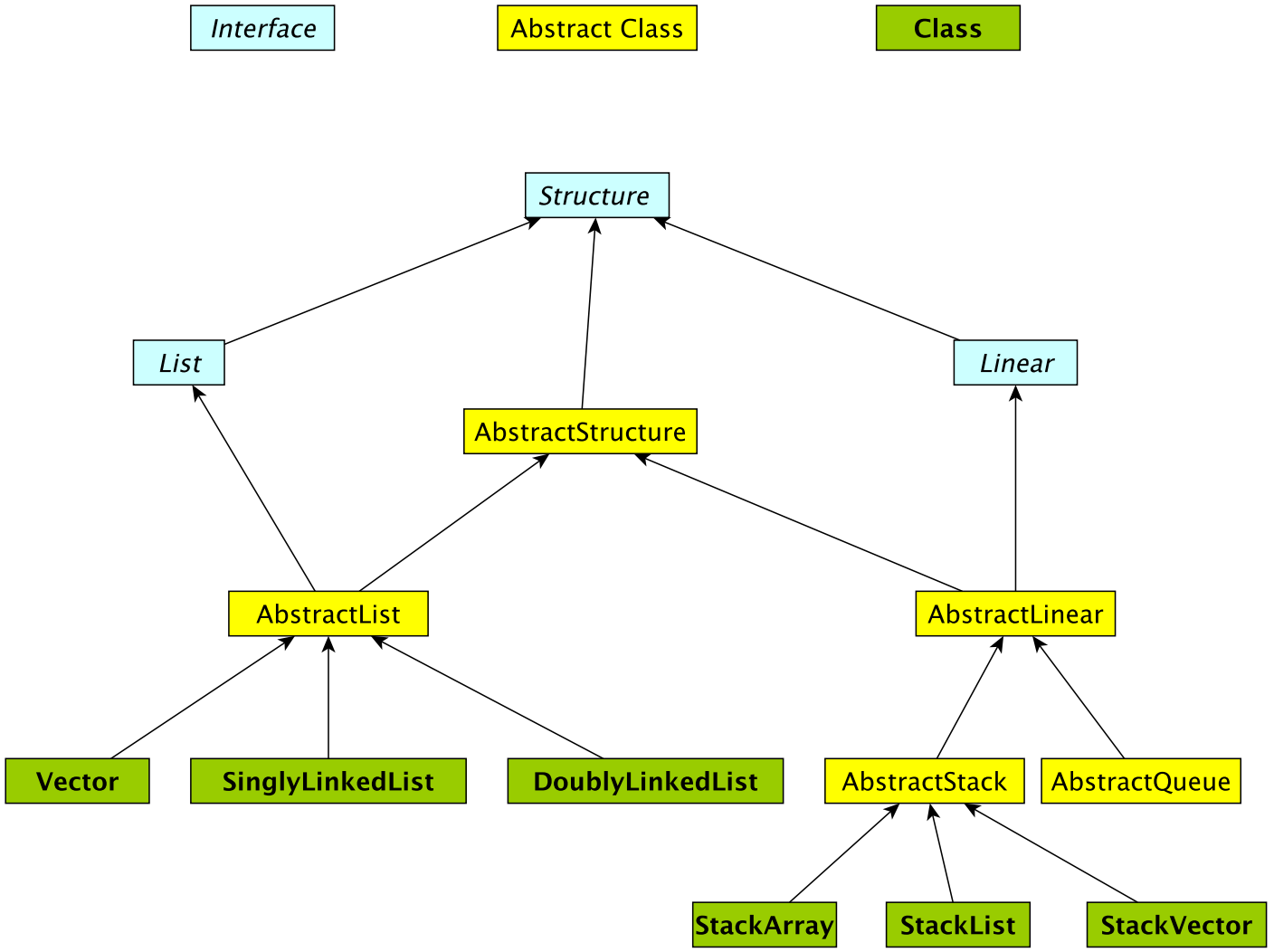
  \+ all operations are O(1)

  +/– O(n) space overhead (no "wasted" space)

Summary Notes on The Hierarchy

- Linear interface *extends* Structure
  - add(E val), empty(), get(), remove(), size()
- AbstractLinear (partially) implements Linear
- AbstractStack class (partially) *extends* AbstractLinear
  - Essentially introduces "stack-ish" names for methods
  - push(E val) is add(E val), pop() is remove(), peek() is get()
- Now we can extend AbstractStack to make "concrete" Stack types
  - StackArray<E>: holds an array of type E; add/remove at high end
  - StackVector<E>: similar, but with a vector for dynamic growth
  - StackList<E>: A singly-linked list with add/remove at head
  - We implement add, empty, get, remove, size directly
    - push, pop, peek are then indirectly implemented

The Structure5 Universe (so far)



Stack Applications

- Stack Implementation is simple, applications are many
  - Evaluating mathematical expressions
  - Searching (Depth-First Search)
  - Removing recursion for optimization
  - Simulations
  - ...

Evaluating Arithmetic Expressions

- Computer programs regularly use stacks to evaluate arithmetic expressions
- Example: x*y+z
  - First rewrite as xy*z+ (we'll look at this rewriting process in more detail soon)
  - Then:
    - push x
    - push y
    - * (pop twice, multiply popped items, push result)
    - push z
    - + (pop twice, add popped items, push result)

Converting Expressions

- We (humans) primarily use "infix" notation to evaluate expressions
  - (x+y)*z
- Computers traditionally used "postfix" (also called Reverse Polish) notation
  - xy+z*
  - Operators appear after operands, parentheses not necessary
- How do we convert between the two?
  - Compilers do this for us

Converting Expressions

- Example: x*y+z*w
- Conversion
  1) Add full parentheses to preserve order of operations

     ((x*y)+(z*w))
  2) Move all operators (+-*/) after operands

     ((xy*)(zw*)+)
  3) Remove parentheses

     xy*zw*+

Use Stack to Evaluate Postfix Exp

- While there are input "tokens" (i.e., symbols) left:
  - Read the next token from input.
  - If the token is a value, push it onto the stack.
  - Else, the token is an operator that takes n arguments.
    - (It is known a priori that the operator takes n arguments.)
    - If there are fewer than n values on the stack → error.
    - Else, pop the top n values from the stack.
      - Evaluate the operator, with the values as arguments.
      - Push the returned result, if any, back onto the stack.
  - The top value on the stack is the result of the calculation.
  - Note that results can be left on stack to be used in future computations:
    - Eg: 3 2 * 4 + followed by 5 / yields 2 on top of stack

Example

- (x*y)+(z*w) → xy*zw*+
- Evaluate:
  - Push x
  - Push y
  - Mult: Pop y, Pop x, Push x*y
  - Push z
  - Push w
  - Mult: Pop w, Pop z, Push z*w
  - Add: Pop x*y, Pop z*w, Push (x*y)+(z*w)
  - Result is now on top of stack

Preview: PostScript

- PostScript is a programming language used for generating vector graphics
  - Best-known application: describing pages to printers
- It is a stack-based language
  - Values are put on stack
  - Operators pop values from stack, put result back on
  - There are numeric, logic, string values
  - Many operators
- Let's try it: The 'gs' command runs a PostScript interpreter….
- You'll be writing a (tiny part of) gs in lab soon....

Preview: PostScript

- Types: numeric, boolean, string, array, dictionary
- Operators: arithmetic, logical, graphic, …
- Procedures
- Variables: for objects and procedures
- PostScript is just as powerful as Java, Python, ...
  - Not as intuitive
  - Easy to automatically generate