CSCI 136
Data Structures & Advanced Programming

Lecture 16

Spring 2018

Profs Bill & Jon

Announcements

- Mid-Term Review Session
  - Tonight (3/12), 7:00-8:00 pm in TPL 203
  - No prepared remarks, so bring questions!
- Modified (extra) office hours (see calendar)
- Mid-term exam is Wednesday, March 14
  - During your normal lab session
  - You'll have 1 hour & 45 minutes (if you come on time!)
  - Closed-book
  - Covers Chapters 1-7 & 9 and all topics up through sorting
  - A "sample" mid-term and study sheet are available online
    - See Handouts & Problem Sets

Last Time

- Sorting Wrap-Up (Merge and Quick)
- Problem Solving Day

Today

- Linear Structures
  - The Linear Interface (LIFO & FIFO)
  - The AbstractLinear and AbstractStack classes
- Stack Implementations
  - StackArray, StackVector, StackList,
- Stack applications
  - Expression Evaluation
  - PostScript: Page Description & Programming

Linear Structures

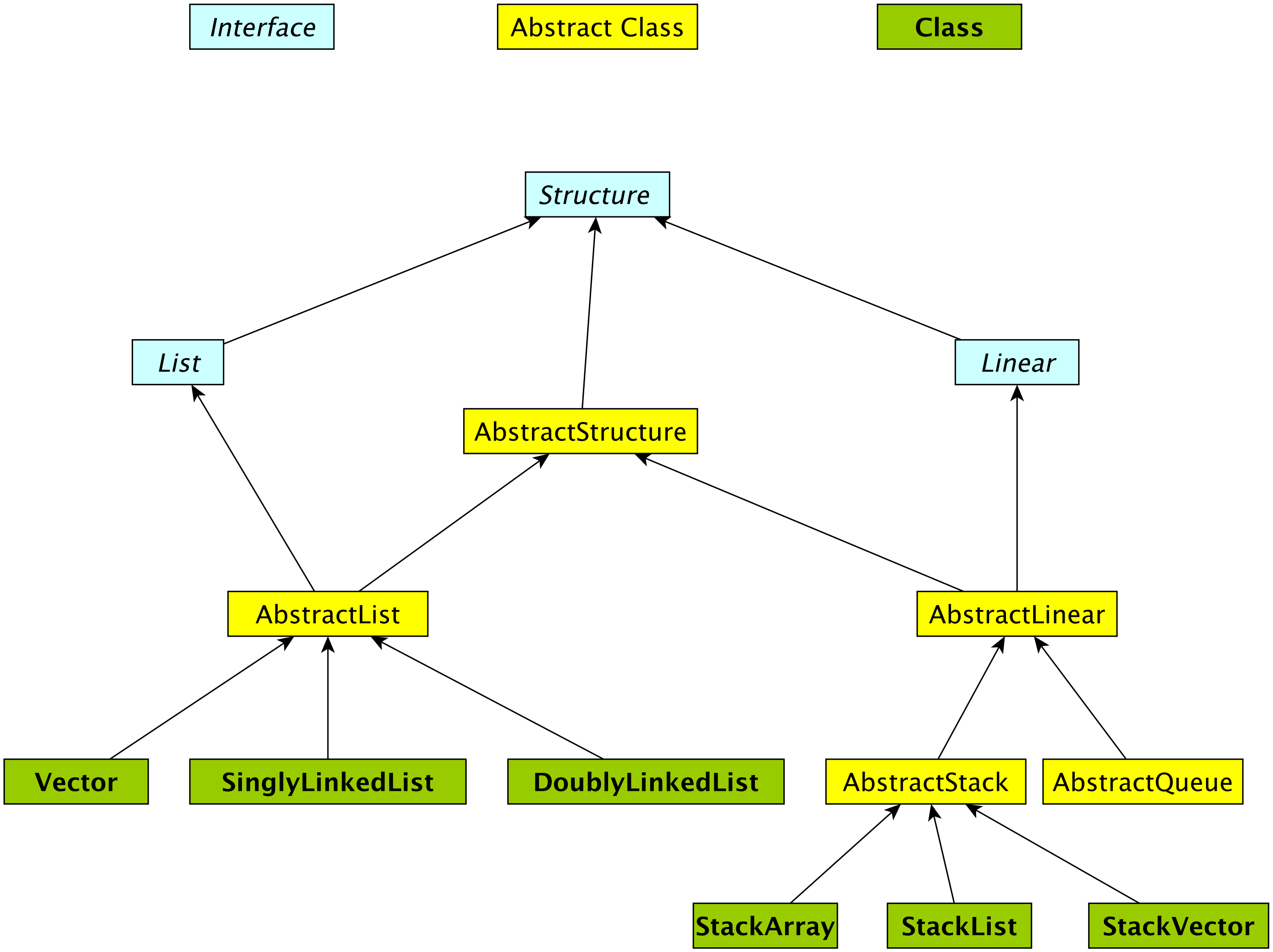
- What if we want to impose *access restrictions* on our lists?
  - I.e., we only provide one way to add and remove elements from list
    - No longer provide access to middle list elements
- Key Examples: removal order depends on the order that elements were added
  - LIFO: Last In First Out
  - FIFO: 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)
  - Pile of trays at dining hall
  - Java Virtual Machine stack

The Structure5 Universe (next)



Interface

Abstract Class

Class

Structure

List

AbstractStructure

Linear

AbstractList

AbstractLinear

Vector

SinglyLinkedList

DoublyLinkedList

AbstractStack

AbstractQueue

StackArray

StackList

StackVector

Linear Interface

- How should `Linear` interface differ from `List`?
  - Should have fewer methods than `List` interface since we are limiting access …
- Methods:
  - Inherits all of the `Structure` interface methods
    - `add(E value)` – Add `value` to the structure.
    - `E remove(E o)` – Remove value o from the structure.
    - `size()`, `isEmpty()`, `clear()`, `contains(E val)`, …
  - 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
  - But less functionality can result in:
    - Simpler implementation
    - Greater efficiency
- Approaches
  - Use existing structures (`Vector`, `LinkedList`), or
  - Use same underlying organization, but simplified

Stacks

- Examples: pile of trays or cups
  - Can only take tray/cup from top of pile
- What methods do we need to define?
  - Stack interface methods
- New terms: `push`, `pop`, `peek`
  - Only 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:
  - push = add
  - pop = remove
  - peek = get
- In Stack interface, push/pop/peek methods call add/remove/get methods that are defined 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)

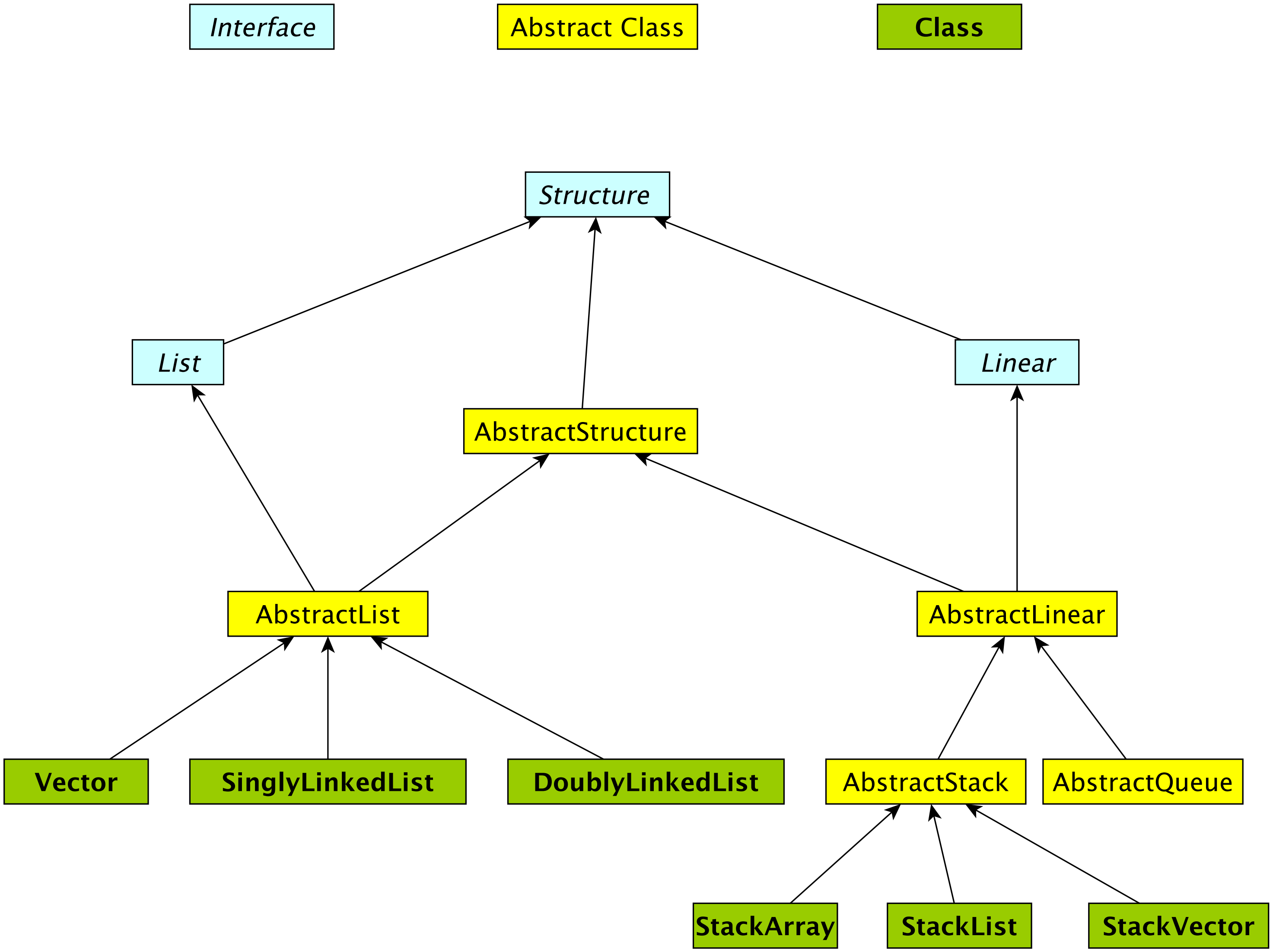
Summary Notes on The Hierarchy

- `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()`

Building The Hierarchy

- 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 to StackArray<E>, but with a vector for dynamic growth
  - `StackList<E>`
    - A singly-linked list with add/remove at `head`
  - For each, we implement `add`, `empty`, `get`, `remove`, `size` directly
    - `push`, `pop`, `peek` are indirectly implemented by abstract class

The Structure5 Universe (so far)



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Stack Applications

- The `Stack` implementation is simple, but there are *many* applictaions
  - 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 are not necessary
- How do we convert between the two?
  - Compilers do this for us