csci 210: Data Structures

Lists and Iterators

Summary

- Topics
  - Java
    - Vector, ArrayList, Stack, LinkedList, Collections
    - extendable arrays
      - analysis
  - Iterators

- READING:
  - GT textbook chapter 6 (6.1 through 6.4)

ArrayLists and Vectors

- classes provided by Java
  - Java.util.ArrayList
  - Java.util.Vector

- practically identical

- provide support for “smart” arrays
  - allow variable size of array
  - support useful methods
    - get(i)
    - set(i,e)
    - add(i,e)
    - remove(i)
    - add(e)
    - size()
    - isEmpty()
- Exercise: implementation
- Notation
  - N is the maximum capacity of the array
  - n is the current size

Performance

- Performance
  - get(i) : O(1)
  - set(i,e): O(1)
  - add(i,e): O(n)
  - remove(i): O(n)
  - size(): O(1)
  - isEmpty(): O(1)
  - add(e): O(1) unless overflow

- ArrayLists and Vectors also grow the array
  - whenever add(e) occurs and the array is full, the array is re-allocated of double size
  - let's say N is the current max capacity of the array A
  - allocate B[] of size 2N
  - copy A[i] into B[i] for all i
  - [free the space of A: note: this does not happen in Java, the garbage collector will find out that the space of A is not in use anymore and will free it]
  - A = B
  - add e to A as usual

Analysis of extendable arrays

- Question: How long does add(e) take?
  - O(1) if the array does not grow
  - O(n) if the arrays grows (need to copy all elements of A to B)
- Suppose you start with an empty array of size 1, and you add n elements. How long will this take?
  - O(n^2) ?
  - 1 + 2 + 3 + 4 + ... +n ?
- Lemma:
  - A sequence of n add() on an initially empty array that grows by doubling take O(n) time.
- Intuition:
  - some add() need to relocate and are slow, but many are O(1)
  - reallocations are not that frequent
  - once the array is reallocated, it is half empty so the next bunch of add() are O(1)

Analysis of extendable arrays

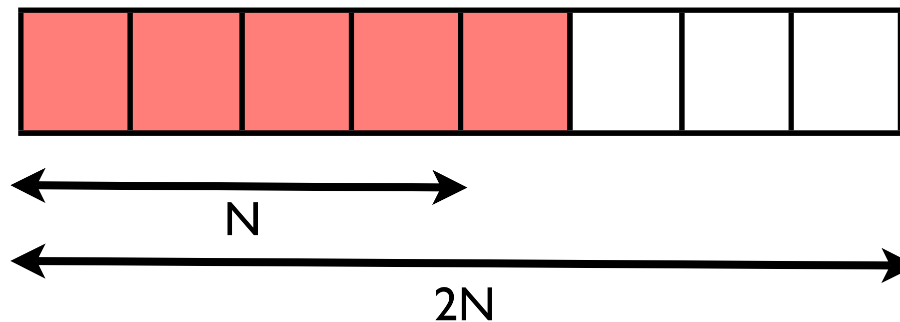
- assume initial capacity of A is 1 and A is empty
- add(e)

		max capacity	cost of copy	cost of add
1	add()	1	-	O(1)
2	add()	2	1	O(1)
3	add()	4	2	O(1)
4	add()		-	O(1)
5	add()	8	4	O(1)
6	add()		-	O(1)
7	add()		-	O(1)
8	add()		-	O(1)
9	add()	16	8	O(1)
...	add()		-	O(1)
17	add()	32	16	O(1)

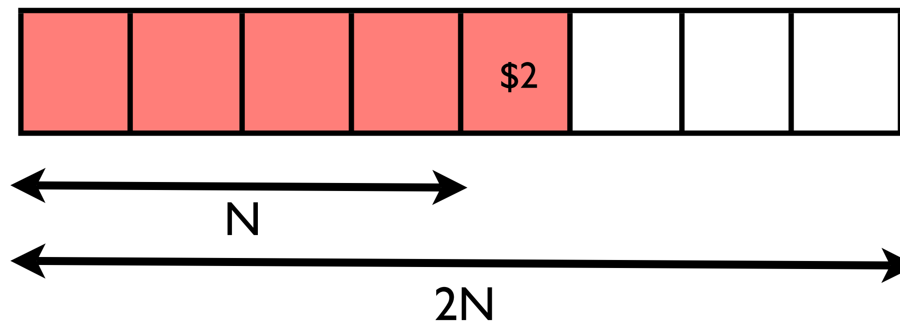
Analysis of extendable arrays

- Imagine you charge each add() $3
  - you use $1 to pay for the actual add()
  - you leave $2 as credit on the element
- We shall prove that the doubling can be paid for by credits accumulated in between doublings.

- Imagine you just doubled the array

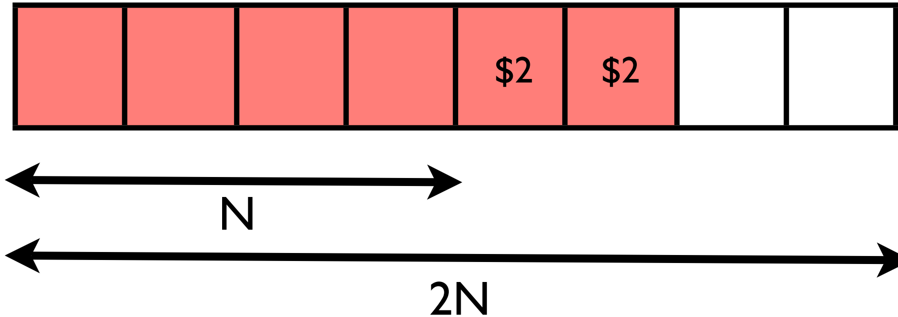


- and you charged this last add() that caused the doubling $3, so you have $2 left

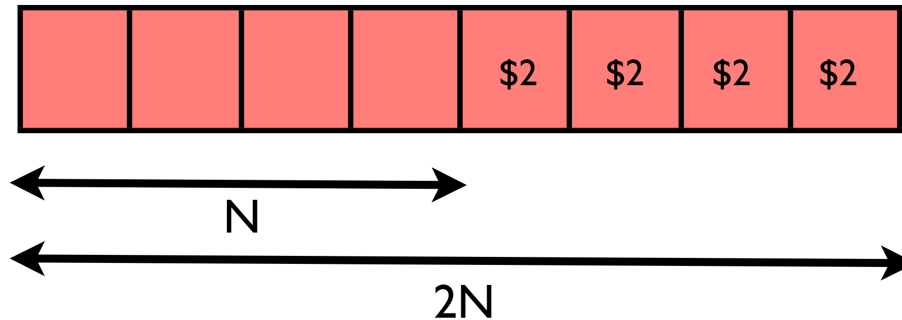


Analysis of extendable arrays

- the next add() : no overflow, O(1)



- ...



- the array gets full again after N add()
  - total credit accumulated: N x $2 = 2N
  - cost of copying the array: 2N

Iterators

- An iterator abstracts the process of scanning through a collection of elements one at a time

- An iterator is a class with the following interface

  - `boolean hasNext()`
    - return true if there are elements left in the iterator

  - `Type  next()`
    - return the next element in the iterator

Iterators in Java

- Java.util.Iterator interface
- Classes that implement collections of elements also support the following method()
  - `iterator()`
    - return an iterator of the elements in the collection
- Example

```
ArrayList<Type> a;
//Vector<Type> a;
//Stack<Type> a;
//LinkedList<Type> a;

Iterator<Type> it = a.iterator();
while (it.hasNext()) {
    Type e = it.next();
    //process e
    //...
}
//or
for (Iterator<Type> it = a.iterator(); it.hasNext();) {
    Type e = it.next();
    //...
}
```

List iterators

- The preferred way to access a Java.util.LinkedList is through an iterator

int	`lastIndexOf(Object o)` Returns the index in this list of the last occurrence of the specified element, or -1 if the list does not contain this elem
`ListIterator`	`listIterator(int index)` Returns a list-iterator of the elements in this list (in proper sequence), starting at the specified position in the list.
`Object`	`remove(int index)`

listIterator

```
public ListIterator listIterator(int index)
```

Returns a list-iterator of the elements in this list (in proper sequence), starting at the specified position in the list. Obeys the general contract of `List.listIterator(int)`.

The list-iterator is *fail-fast*: if the list is structurally modified at any time after the Iterator is created, in any way except through the list-iterator's own `remove` or `add` methods, the list-iterator will throw a `ConcurrentModificationException`. Thus, in the face of concurrent modification, the iterator fails quickly and cleanly, rather than risking arbitrary, non-deterministic behavior at an undetermined time in the future.

Specified by:
`listIterator` in interface `List`

Specified by:
`listIterator` in class `AbstractSequentialList`

Parameters:
`index` - index of first element to be returned from the list-iterator (by a call to `next`).

Returns:
a ListIterator of the elements in this list (in proper sequence), starting at the specified position in the list.

Throws:
`IndexOutOfBoundsException` - if index is out of range (`index < 0 || index > size()`).

See Also:
`List.listIterator(int)`

- a ListIterator includes

Method Summary	
void	add(Object o) Inserts the specified element into the list (optional operation).
boolean	hasNext() Returns true if this list iterator has more elements when traversing the list in the forward direction.
boolean	hasPrevious() Returns true if this list iterator has more elements when traversing the list in the reverse direction.
Object	next() Returns the next element in the list.
int	nextIndex() Returns the index of the element that would be returned by a subsequent call to next.
Object	previous() Returns the previous element in the list.
int	previousIndex() Returns the index of the element that would be returned by a subsequent call to previous.
void	remove() Removes from the list the last element that was returned by next or previous (optional operation).
void	set(Object o) Replaces the last element returned by next or previous with the specified element (optional operation).

Iterators

- Why use iterators?
  - More generic code
    - you can change the data structure, and the loop remains the same