CS61B Lecture #17

Topics

standard Java Collections classes.

, ListIterators

s and maps in the abstract

nalysis of implementing lists with arrays.

Data Types in the Abstract

time, should *not* worry about implementation of data
earch, etc.

o for us—their specification—is important.

eral standard types (in `java.util`) to represent collec-
cts

aces:

tion: General collections of items.

ndexed sequences with duplication

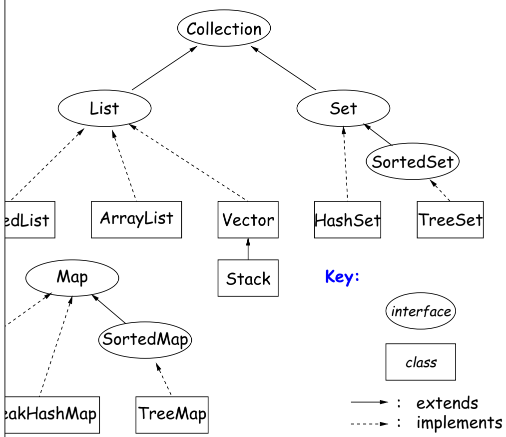
rtedSet: Collections without duplication

rtedMap: Dictionaries (key ↦ value)

classes that provide actual instances: `LinkedList`, `ArrayList`,
`TreeSet`.

hange easier, purists would use the concrete types only
nterfaces for parameter types, local variables.

Collection Structures in java.util



The Collection Interface

erface. Main functions promised:

ip tests: `contains` (∈), `containsAll` (⊆)

ries: `size`, `isEmpty`

`iterator`, `toArray`

modifiers: `add`, `addAll`, `clear`, `remove`, `removeAll` (set
e), `retainAll` (intersect)

bout Library Design: Optional Operations

ections need to be modifiable; often makes sense just
from them.

rations are optional (`add`, `addAll`, `clear`, `remove`, `removeAll`,

developers decided to have *all* Collections implement
lowed implementations to throw an exception:

    UnsupportedOperationException

e design would have created separate interfaces:

```
lection { contains, containsAll, size, iterator, ... }
andable extends Collection { add, addAll }
inkable extends Collection { remove, removeAll, ... }
ifiableCollection
llection, Expandable, Shrinkable { }
```

ave lots of interfaces. Perhaps that's why they didn't
y.

The List Interface

lection

represent *indexed sequences* (generalized arrays)

thods to those of Collection:

ip tests: indexOf, lastIndexOf.

get(i), listIterator(), sublist(B, E).

: add and addAll with additional index to say *where* to wise for removal operations. set operation to go with

erator<Item> extends Iterator<Item>:

vious and hasPrevious.

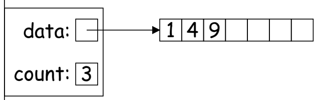
e, and set allow one to iterate through a list, inserting, or changing as you go.

t Question: What advantage is there to saying List L an LinkedList L or ArrayList L?

nplementing Lists (I): ArrayLists

ncrete types in Java library for interface List are nd LinkedList:

t expect, an ArrayList, A, uses an array to hold data. , a list containing the three items 1, 4, and 9 might be like this:



four more items to A, its data array will be full, and data will have to be replaced with a pointer to a new, that starts with a copy of its previous values.

r best performance, how big should this new array be?

se the size by 1 each time it gets full (or by any con- the cost of N additions will scale as $\Theta(N^2)$, which List look much worse than LinkedList (which uses an implementation.)

Amortization: Expanding Vectors

array for expanding sequence, best to *double* the size row it. Here's why.

ze s, doubling its size and moving s elements to the new time proportional to $2s$.

there is an additional $\Theta(1)$ cost for each addtion to actually assigning the new value into the array.

ld up these costs for inserting a sequence of N items, st turns out to proportional to N, as if each addition t time, even though some of the additions actually take ional to N all by themselves!

ortization: Expanding Vectors (II)

	Resizing Cost	Cumulative Cost	Resizing Cost per Item	Array Size After Insertions
	0	0	0	1
	2	2	1	2
	4	6	2	4
	0	6	1.5	4
	8	14	2.8	8
	0	14	2.33	8
	⋮	⋮	⋮	⋮
	0	14	1.75	8
	16	30	3.33	16
	⋮	⋮	⋮	⋮
	0	30	1.88	16
	⋮	⋮	⋮	⋮
-1	0	$2^{m+2}-2$	≈ 2	2^{m+1}
	2^{m+2}	$2^{m+3}-2$	≈ 4	2^{m+2}

d out (*amortize*) the cost of resizing, we average at time units on each item: "amortized insertion time is 4 to add N elements is $\Theta(N)$, *not* $\Theta(N^2)$.

ating Amortized Time: Potential Method

the argument, associate a *potential*, $\Phi_i \geq 0$, to the i^{th} at keeps track of "saved up" time from cheap operations 'spend" on later expensive ones. Start with $\Phi_0 = 0$.

end that the cost of the i^{th} operation is actually a_i, the *st*, defined

$$a_i = c_i + \Phi_{i+1} - \Phi_i,$$

ne real cost of the operation. Or, looking at potential:

$$\Phi_{i+1} = \Phi_i + (a_i - c_i)$$

erations, we artificially set $a_i > c_i$ so that we can in- $_{+1} > \Phi_i$).

ones, we typically have $a_i \ll c_i$ and greatly decrease Φ t it go negative—may not be "overdrawn").

all this so that a_i remains as we desired (e.g., $O(1)$ for ray), without allowing $\Phi_i < 0$.

t we choose a_i so that Φ_i always stays ahead of c_i.

Application to Expanding Arrays

to our array, the cost, c_i, of adding element #i when eady has space for it is 1 unit.

es not initially have space when adding items 1, 2, 4, 8, er words at item 2^n for all $n \geq 0$. So,

≥ 0 and is not a power of 2; and

1 when i is a power of 2 (copy i items, clear another i then add item #i).

peration #2^n we're going to need to have saved up at $^{n+1}$ units of potential to cover the expense of expanding nd we have this operation and the preceding $2^{n-1} - 1$ which to save up this much potential (everything since g doubling operation).

= 1 and $a_i = 5$ for $i > 0$. Apply $\Phi_{i+1} = \Phi_i + (a_i - c_i)$, and happens:

4	5	6	7	8	9	10	11	12	13	14	15	16	17
9	1	1	1	17	1	1	1	1	1	1	1	33	1
5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	2	6	10	14	2	6	10	14	18	22	26	30	2

Pretending each cost is 5 never underestimates true cumulative time.