Return of the ArrayList: analyzing the running time of resizing

/*
A List that is implemented using an array
*/

public class ArrayList implements List {
    private Object[] elements;
    private int numElements;

    @Override
    public void append(Object ele) {
        // copy existing elements to a bigger array if necessary
        if (elements.length == numElements) {
            Object[] n = new Object[elements.length+1];
            for (int i=0; i<elements.length; i++) {
                n[i] = elements[i];
            }
            elements = n;
        }
        // insert ele
        elements[numElements] = ele;
        numElements++;
    }
}
Return of the ArrayList: an analysis of resizing

If it takes one “step” to copy one element, about how many total steps will be taken to call append 1000 times when the initial size was 4?

a) 1000  
b) 2000  
c) 1,000,000  
d) 1,000,000,000

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Simulate this new scenario
Calculate the total time by a simple simulation!

steps = 0
# initially ArrayList's internal array is size 4
arraysize = 4
for n in range(1, 1001):
    if n > arraysize:
        # ArrayList is full so n steps to copy to new array of size 2n
        steps += n
        # new array has x2 size
        arraysize *= 2
    # 1 step to copy the new value into the next open spot
    steps += 1

print str(n)+"\t"+str(steps)

(num eles \textit{and} num total steps)

(not the same as an experiment, where we actually
time time the ArrayList insertions)
some insertions take a long time, but the total time is growing linearly!

# calls to append
Part 1

[Diagram showing two lists, one full and one empty]

Part 2

[Diagram showing a list with a single element and a note: O(n)]

worst case

best case: O(1)

step to put element here

avg case?
some insertions take a long time, but the total time is growing linearly!

# calls to append

total time to insert
best  \frac{P_1}{O(1)}  \frac{P_2}{O(1)}
worst  \frac{O(N)}{O(N)}  \frac{O(W)}{O(W)}

avg  \frac{75.0}{7.50}  \frac{75.0}{7.50}