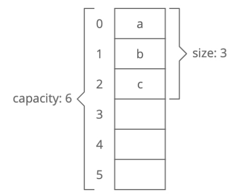


Dynamic Array

Data Structure

Other names:
array list, growable array, resizable array, mutable array

Quick reference

A **dynamic array** is an array with a big improvement: automatic resizing.

One limitation of arrays is that they're *fixed size*, meaning you need to specify the number of elements your array will hold ahead of time.

A dynamic array expands as you add more elements. So you *don't* need to determine the size ahead of time.

	Average Case	Worst Case
space	$O(n)$	$O(n)$
lookup	$O(1)$	$O(1)$
append	$O(1)$	$O(n)$
insert	$O(n)$	$O(n)$
delete	$O(n)$	$O(n)$

Strengths:

- **Fast lookups**. Just like arrays, retrieving the element at a given index takes $O(1)$ time.
- **Variable size**. You can add as many items as you want, and the dynamic array will expand to hold them.
- **Cache-friendly**. Just like arrays, dynamic arrays place items right next to each other in memory, making efficient use of caches.

Weaknesses:

- **Slow worst-case appends**. Usually, adding a new element at the end of the dynamic array takes $O(1)$ time. *But* if the dynamic array doesn't have any room for the new item, it'll need to expand, which takes $O(n)$ time.
- **Costly inserts and deletes.** Just like arrays, elements are stored adjacent to each other. So adding or removing an item in the middle of the array requires "scooting over" other elements, which takes $O(n)$ time.

In Python 3.6

In Python, dynamic arrays are called *lists*.

Here's what they look like:

Python 2.7

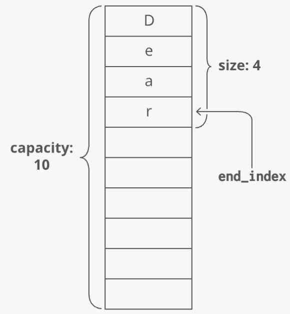
```
gas_prices = []

gas_prices.append(346)
gas_prices.append(360)
gas_prices.append(354)
```

Size vs. Capacity

When you allocate a dynamic array, your dynamic array implementation makes an *underlying fixed-size array*. The starting size depends on the implementation—let's say our implementation uses 10 indices. Now say we append 4 items to our dynamic array. At this point, our dynamic array has a length of 4. But the *underlying array* has a length of 10.

We'd say this dynamic array's **size** is 4 and its **capacity** is 10. The dynamic array stores an `end_index` to keep track of where the dynamic array ends and the extra capacity begins.



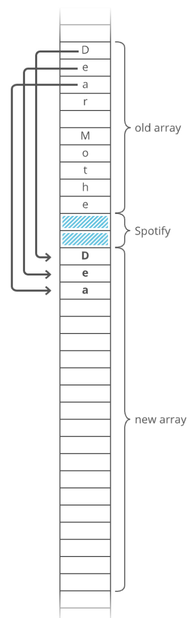
Doubling Appends

What if we try to append an item but our array's capacity is already full?

To make room, dynamic arrays automatically make a new, bigger underlying array. Usually twice as big.

> Why not just *extend* the existing array? Because that memory might already be taken by another program.

Each item has to be individually copied into the new array.



Copying each item over costs $O(n)$ time! So whenever appending an item to our dynamic array forces us to make a new double-size underlying array, that append takes $O(n)$ time.

That's the *worst* case. But in the best case (and the *average* case), appends are just $O(1)$ time.

Amortized cost of appending

1. The time cost of each special $O(n)$ "doubling append" *doubles* each time.
2. At the same time, the *number of $O(1)$ appends* you get until the *next doubling* append *also* doubles.

These two things sort of "cancel out," and we can say each append has an *average* cost or **amortized cost** of $O(1)$.

Given this, in industry we usually wave our hands and say dynamic arrays have a time cost of $O(1)$ for appends, even though strictly speaking that's only true for the *average* case or the *amortized* cost.

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