COMP110: Principles of Computing

8: Basic Data Structures

Learning outcomes

- **Distinguish** basic data structures such as arrays, linked lists and associative maps
- **Determine** the complexity of accessing and manipulating data in these data structures
- **Choose** the correct data structure for a given task

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Research Journal Peer Review

Basic containers in Python

Memory allocation

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- Blocks can be allocated and deallocated at will, but can **never grow or shrink**

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  - Hide the details of memory allocation, and allow the programmer to write simpler code
- Containers are an **encapsulation**
  - Bundle together the data's representation in memory along with the algorithms for accessing it

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- E.g. if the array starts at address 1000 and each element is 4 bytes, the 3rd element is at address $1000 + 4 \times 3 = 1012$
- Accessing an array element is **constant time** $O(1)$

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- When the list needs to change size, it **creates** a new array, **copies** the contents of the old array, and **deletes** the old array
- Implementation details: `http://www.laurentluce.com/posts/python-list-implementation/`

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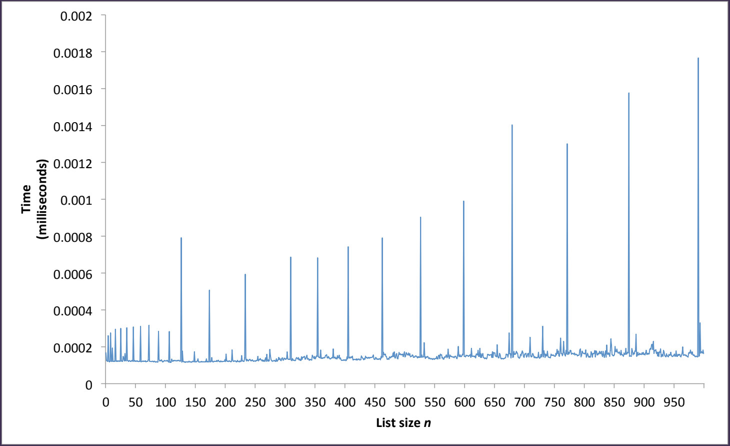
Time taken to append an element to a list of size *n*



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- **Inserting** anywhere other than the end is **linear time**
  - Can't just insert new bytes into a memory block — need to move all subsequent list elements to make room
- Similarly, **deleting** anything other than the last element is **linear time**

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- Create tuples with `()`, just as you create lists with `[]`
  - Exception: a single element tuple is created as `(foo,)` because `(foo)` would be interpreted as a bracketed expression
- Can often omit the parentheses entirely, e.g.

```
my_tuple = 1,2,3
```

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Unpacking

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- Unpacking requires the number of elements to match exactly — if `foo` has more than 4 elements, the code on the left will give an error

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```
temp = a
a = b
b = temp
```

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- Hence building a long string by appending can be slow (appending strings is $O(n)$)

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  - Values can be anything (including dictionaries or other containers)
- A dictionary is implemented as a **hash table**

Using dictionaries

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Create them using `{}`:

```
age = {"Alice": 23, "Bob": 36, "Charlie": 27}
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Access values using `[]`:

```
print age["Alice"]   # prints 23
age["Bob"] = 40      # overwriting an existing item
age["Denise"] = 21   # adding a new item
```

Iterating over dictionaries

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Iterating over a dictionary gives the **keys**:

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    print x    # prints Alice, Bob, Charlie
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Use `iteritems` to get **key,value** pairs:

```
for key, value in age.iteritems():
    print key, "is", age, "years old"
```

Dictionaries are unordered

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What does this print?

```
square_root = {}
for i in xrange(30):
    square_root[i*i] = i

for key, value in square_root.iteritems():
    print "The square root of", key, "is", value
```

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Dictionaries are **unordered** — never rely on the order of their elements, because the order isn't guaranteed!

Sets

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Operation	List	Set
Add element	Append: $O(1)$ Insert: $O(n)$	$O(1)$
Delete element	$O(n)$	$O(1)$
Contains element?	$O(n)$	$O(1)$

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- For "plain old data" (e.g. numbers), this is accurate
- For **objects** (i.e. instances of classes), variables actually hold **references** (a.k.a. **pointers**)
- It is possible (indeed common) to have **multiple references** to the same underlying object

The wrong picture

```
class Thing:
    def __init__(self,
                 a, b):
        self.a = a
        self.b = b

x = Thing(30, 40)
y = Thing(50, 60)
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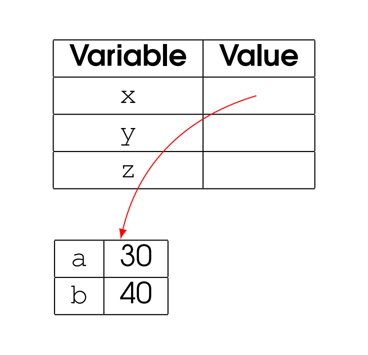

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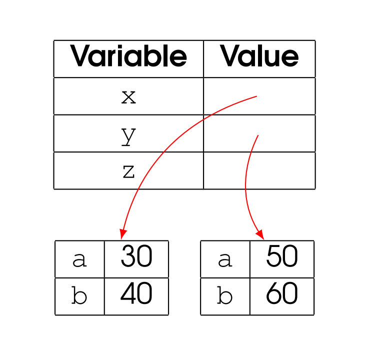

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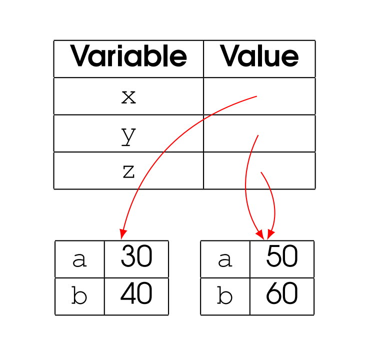

Values and references

Socrative room code: `FALCOMPED`

```
a = 10
b = a
a = 20
print "a:", a
print "b:", b
```

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Socrative room code: `FALCOMPED`

```
class X:
    def __init__(self, value):
        self.value = value

a = X(10)
b = a
a.value = 20
print "a:", a.value
print "b:", b.value
```

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Socrative room code: `FALCOMPED`

```
class X:
    def __init__(self, value):
        self.value = value

a = X(10)
b = X(10)
a.value = 20
print "a:", a.value
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def double(x):
    x *= 2

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print a
```

`double` does not actually do anything, as `x` is just a local copy of whatever is passed in!

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However, instances are passed by **reference**

```
class Box:
    def __init__(self, v):
        self.value = v

def double(x):
    x.value *= 2

a = Box(7)
double(a)
print a.value
```

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However, instances are passed by **reference**

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class Box:
    def __init__(self, v):
        self.value = v

def double(x):
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a = Box(7)
double(a)
print a.value
```

`double` now has an effect, as `x` gets a reference to the `Box` instance

Lists are objects too

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```
a = ["Hello"]
b = a
b.append("world")
print a  # ["Hello", "world"]
```

Lists are objects too

```
a = ["Hello"]
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b.append("world")
print a   # ["Hello", "world"]
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... which means you should be careful when passing lists into functions, because the function might actually change the list!