COMP110: Principles of Computing

9: Data Structures II

Exercise Sheet iii

Due **tomorrow**

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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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- Accessing an array element is **constant time** $O(1)$

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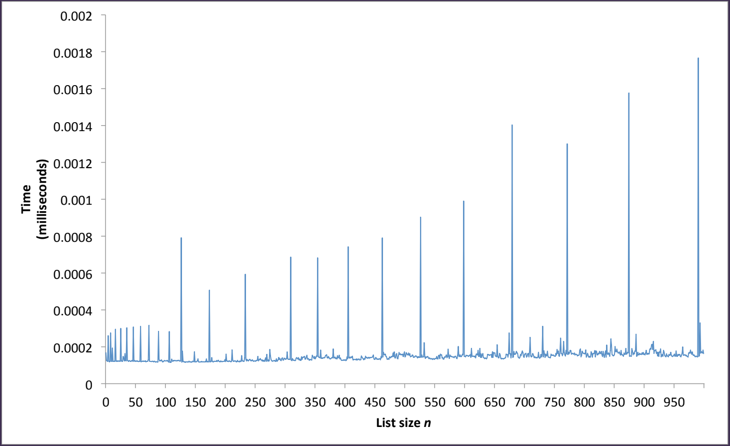
- When the list needs to change size, it **creates** a new array, **copies** the contents of the old array, and **deletes** the old array
- Implementation details: `http://www.laurentluce.com/posts/python-list-implementation/`

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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  - E.g. *xy* coordinates, RGB colours, ...
- 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 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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- This isn't changing the string, it's creating a new one and throwing the old one away!
- Hence building a long string by appending can be slow (appending strings is $O(n)$)

Dictionaries

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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 `{}`:

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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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for x in age:
    print(x)    # prints Alice, Bob, Charlie
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Use `items` to get **key,value** pairs:

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

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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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Test membership with `in` operator

```
if 9 in numbers:
    print("Set contains 9")
```

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2-dimensional arrays

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$$
\begin{matrix}
v_{0,0} & v_{1,0} & \cdots & v_{w-1,0} \\
v_{0,1} & v_{1,1} & \cdots & v_{w-1,1} \\
\vdots & \vdots & \ddots & \vdots \\
v_{0,h-1} & v_{1,h-1} & \cdots & v_{w-1,h-1}
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- The element in column x row y is accessed by `list[y * w + x]`
- E.g. $w = 5, h = 4$:

0	1	2	3	4
5	6	7	8	9
10	11	12	13	14
15	16	17	18	19

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  - Each element of the "outer" list represents a column of the array
- The element in column x row y is accessed by `list[x][y]`, i.e. the yth element of the xth column

Approach 3: dictionary

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- The element in column *x* row *y* is accessed by `list[x, y]`

Approach 4: NumPy array

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- However, highly optimised for intensive calculations (e.g. “tinkering” with image pixel colours...?)

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There is no single "best" approach — it depends how you use it

Worksheet D

Due **next week**

Exercise Sheet iii