CS101 - String, Set, Dictionary and Image Processing

Lecture 7

School of Computing
KAIST
Roadmap

Last week we learned

- Sequences
  - Lists
  - Strings
  - Tuples
Roadmap

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- Sequences
  - Lists
  - Strings
  - Tuples

This week we will learn

- Data structures
  - String
  - Set
  - Dictionary
- Image processing
Formatting

We often want to produce nicely formatted output:

```python
print("Max between " + str(x0) + " and " + str(x1) + " is " + str(val))
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format_string % (arg0, arg1, .... )
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print("Max between %d and %d is %g" % (x0, x1, val))
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Formatting operator:

```python
format_string % (arg0, arg1, ....)
```

Tuple has one element for each place holder in the `format_string`. Place holders are:

- `%d` for integers in decimal
- `%g` for float
- `.2f` for float with fixed precision (2 digits after period)
- `%s` for anything (like `str(x)`)
If there is only one place holder, tuple is not necessary:

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print("Maximum is %g" % val)
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We can align table by using field width:

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print("%3d ~ %3d: %10g" % (x0, x1, x2))
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print("%3d ~ %3d: %10g" % (x0, x1, x2))
```

A value can be left-aligned in its field:

```python
print("%3d ~ %-3d: %-12g" % (x0, x1, x2))
```
Strings

Strings are sequences:

def is_palindrome(s):
    for i in range(len(s) // 2):
        if s[i] != s[len(s) - i - 1]:
            return False
    return True

return True
Strings

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Strings

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        if s[i] != s[len(s) - i - 1]:
            return False
    return True
```

Strings are immutable.

The `in` operator for strings:

```python
>>> "abc" in "01234abcdefg"
True
>>> "abce" in "01234abcdefg"
False
```

Different from the `in` operator for lists and tuples, which tests whether something is equal to an element of the list or tuple.
String methods

String objects have many useful methods:

- `upper()`, `lower()` and `capitalize()`
- `isalpha()` and `isdigit()`
- `startswith(prefix)` and `endswith(suffix)`
- `find(str1)`, `find(str1, start)` and `find(str1, start, end)`
- `replace(str1, str2)`
- `rstrip()`, `lstrip()` and `strip()`
- `split()` and `split(sep)`
- `join(list1)`

All methods are described in the Python document.
Set

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```python
>>> odds = {1, 3, 5, 7, 9}
>>> evens = {2, 4, 6, 8, 10}
>>> emptyset = set()  # {} creates an empty dictionary
>>> randomset = {4, 6, 2, 7, 5, 2, 3}  # Duplicated ele.
```
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>>> odds
{9, 3, 5, 1, 7}
>>> evens
{8, 10, 2, 4, 6}
>>> emptyset
set()
>>> randomset
{2, 3, 4, 5, 6, 7}
```
We can convert a list to a set

```python
>>> gold = [0, 4, 5, 10, 3, 0, 2, 1, 4, 8, 1, 0, 1, 0, 0, 8, 11, 4, 13, 1, 2, 3, 2, 6, 1, 9]
>>> gold
[0, 4, 5, 10, 3, 0, 2, 1, 4, 8, 1, 0, 1, 0, 0, 8, 11, 4, 13, 1, 2, 3, 2, 6, 1, 9]
>>> goldset = set(gold)
>>> goldset
{0, 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 13}
>>> type(goldset)
<class 'set'>
```
Set

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>>> gold
[0, 4, 5, 10, 3, 0, 2, 1, 4, 8, 1, 0, 1, 0, 0, 8, 11, 4, 13, 1, 2, 3, 2, 6, 1, 9]
>>> goldset = set(gold)
>>> goldset
{0, 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 13}
>>> type(goldset)
<class 'set'>
```

We can also convert a string to set

```python
>>> set("Good morning!")
{'G', 'm', 'i', 'd', 'o', '!', 'g', 'n', 'r', ' '}
```
Set

A set does not have ordering, so indexing is not supported.

```python
evens = [1, 3, 5, 7, 9]
evens[1]  # TypeError
```

We use the `in` operator for sets.

```python
evens = [1, 3, 5, 7, 9]
3 in evens  # True
2 in evens  # False
```
Set

A set does not have ordering, so indexing is not supported.

```python
>>> odds[1]
TypeError: 'set' object does not support indexing
```

We use `in` operator for sets

```python
>>> 3 in odds
True
>>> 2 in odds
False
>>> for num in odds:
    ... print(num)
9
3
5
1
7
```
Set methods

The set objects $s$ have the following methods:

- $s.add(v)$: adds an element $v$
- $s.remove(v)$: removes an element $v$
- $s.pop()$: removes and returns an arbitrary element
- $s.intersection(k)$: returns the intersection between the sets $s$ and $k$ (i.e., $s \cap k$)
- $s.union(k)$: returns the union of the sets $s$ and $k$ (i.e., $s \cup k$)
- $s.difference(k)$: removes elements found in a set $k$ (i.e., $s \cap k^c$)
Set methods

Examples of using the set methods

```python
>>> randomset
{2, 3, 4, 5, 6, 7}
>>> randomset.add(9)
>>> randomset
{2, 3, 4, 5, 6, 7, 9}
>>> randomset.remove(7)
>>> randomset
{2, 3, 4, 5, 6, 9}
>>> randomset.pop()
2
>>> randomset
{3, 4, 5, 6, 9}
```
Examples of using the set methods - continued

```python
>>> randomset
{3, 4, 5, 6, 9}
>>> randomset.intersection(odds)
{9, 3, 5}
>>> randomset.union(evens)
{2, 3, 4, 5, 6, 8, 9, 10}
>>> randomset.difference(odds)
{4, 6}
>>> odds.difference(randomset)
{1, 7}
>>> randomset.difference(odds, evens)
set()
```
Another useful data structure in Python is *dictionary*. Similar to lists and sets, a dictionary is a collection of values. However, a dictionary can be accessed by using multiple types of indexes (i.e., not only integers, but also strings and any immutable types of objects). Indexes used for a dictionary are called *keys*, and a key is associated with a *value*. This is called a *key-value pair*.
Another useful data structure in Python is dictionary.

Similar to lists and sets, a dictionary is a collection of values. However, a dictionary can be accessed by using multiple types of indexes (i.e., not only integers, but also strings and any immutable types of objects). Indexes used for a dictionary are called keys, and a key is associated with a value. This is called a key-value pair.

To create a dictionary, we can use curly braces or the `dict()` function.

```python
majors = {"CS": "Computer Science",
          "EE": "Electrical Engineering",
          "MAS": "Mathematical Sciences",
          "ME": "Mechanical Engineering"}

d1 = dict()  # an empty dictionary
d2 = {}      # an empty dictionary
```
Dictionary

A dictionary does not have ordering, and only the keys that are defined in a dictionary can be used as an index.

```python
>>> majors[0]
KeyError: 0
```
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```python
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```

We can add a key with a value to a dictionary.

```python
>>> majors["PH"] = "Physic"
>>> majors["PH"]
'Physic'
```
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>>> majors["PH"] = "Physic"
```

```python
>>> majors["PH"]
'Physic'
```

We can also change the value via the key in the dictionary.

```python
>>> majors["PH"] = "Physics"
```

```python
>>> majors["PH"]
'Physics'
```
Dictionary methods

A dictionary object `d` has the following methods and operators

- `len(d)`: returns the number of elements in `d`
- `key in d`: returns `True` if `d` has the `key`, otherwise returns `False`
- `d.get(key, default=None)`: Returns the value that corresponds to the `key`, or returns the `default` value if the `key` is not defined in `d`
- `d.keys()`: returns a list of keys in `d`
- `d.values()`: returns a list of values in `d`
- `d.items()`: returns a list of key-value pairs in `d`
- `del d[key]`: removes the key-value pair that corresponds to the `key`

The objects that are returned from `keys()`, `values()` and `items()` are not list objects. They have elements like lists, but they cannot be modified and do not have an `append()` method.
Examples of using the dictionary methods

```python
>>> majors
{0: 0.001, 'CS': 'Computer Science', 'PH': 'Physics', 'ME': 'Mechanical Engineering', 'EE': 'Electrical Engineering', 'MAS': 'Mathematical Sciences'}

>>> len(majors)
6

>>> del majors[0]

>>> majors
{'CS': 'Computer Science', 'PH': 'Physics', 'ME': 'Mechanical Engineering', 'EE': 'Electrical Engineering', 'MAS': 'Mathematical Sciences'}

>>> len(majors)
5

>>> "CS" in majors
True

>>> "AI" in majors
False
```
Examples of using the dictionary methods - continued

```python
>>> majors.keys()
dict_keys(['CS', 'PH', 'ME', 'EE', 'MAS'])
```
```
>>> majors.values()
dict_values(['Computer Science', 'Physics',
'Mechanical Engineering', 'Electrical Engineering',
'Mathematical Sciences'])
```
```
>>> majors.items()
dict_items([('CS','Computer Science'), ('PH','Physics'),
('ME','Mechanical Engineering'), ('EE','Electrical Engineering'),
('MAS','Mathematical Sciences')])
```
Loop in a dictionary

To loop over the keys in a dictionary, we can use the `in` operator

```python
>>> for key in majors:
...     print("%s is %s." % (key, majors[key]))
CS is Computer Science.
PH is Physics.
ME is Mechanical Engineering.
EE is Electrical Engineering.
MAS is Mathematical Sciences.
```
Loop in a dictionary

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```python
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...    print("%s is %s." % (key, majors[key]))
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PH is Physics.
ME is Mechanical Engineering.
EE is Electrical Engineering.
MAS is Mathematical Sciences.
```

To loop over both keys and values in a dictionary, we can use `items()`

```python
>>> for key, value in majors.items():
...    print("%s is %s." % (key, value))
CS is Computer Science.
PH is Physics.
ME is Mechanical Engineering.
EE is Electrical Engineering.
MAS is Mathematical Sciences.
```
List, Set and Dictionary

When do we use list, set or dictionary?

- If we need to manage an ordered sequence of objects
  -> Use a List

- If we need to manage an unordered set of values
  -> Use a Set

- If we need to associate values with keys, so that we can easily look up the values by the keys
  -> Use a Dictionary
List, Set and Dictionary

Using a set is more efficient than using a list when we check membership of a value.

```python
import time
large_list = list(range(10000000))
large_set = set(large_list)

st = time.time()
for num in range(100000):
    if num not in large_list:
        print("What?!")
print("Running time for list: %f sec" % (time.time() - st))

st = time.time()
for num in range(100000):
    if num not in large_set:
        print("What?!")
print("Running time for set: %f sec" % (time.time() - st))
```
List, Set and Dictionary

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for num in range(100000):
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        print("What?!")
print("Running time for list: \%f sec" % (time.time() - st))

st = time.time()
for num in range(100000):
    if num not in large_set:
        print("What?!")
print("Running time for set: \%f sec" % (time.time() - st))

Result:
Running time for list: 78.066966 sec
Running time for set: 0.010978 sec
```
Copy and paste

Let’s put the KAIST statue on a nice background:

```
def paste(canvas, img, x1, y1):
    w, h = img.size()
    for y in range(h):
        for x in range(w):
            canvas.set(x1 + x, y1 + y, img.get(x, y))
```
Chromakey

Chromakey is a technique to overlay one scene on top of another one. It is commonly used for weather maps.
Color distance

Actually, the background is not exactly blue - just blueish. We need a function to decide how similar two colors are:

```python
def dist(c1, c2):
    r1, g1, b1 = c1
    r2, g2, b2 = c2
    return math.sqrt((r1-r2)**2 + (g1-g2)**2 + (b1-b2)**2)
```

This is just the Euclidean distance in $\mathbb{R}^3$. 

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```

This is just the Euclidean distance in $\mathbb{R}^3$. 
def chroma(img, key, threshold):
    w, h = img.size()
    for y in range(h):
        for x in range(w):
            p = img.get(x, y)
            if dist(p, key) < threshold:
                img.set(x, y, Color.yellow)
Chromakey

Now all we need is a paste function that skips the color-coded background:

```python
def chroma_paste(canvas, img, x1, y1, key):
    w, h = img.size()
    for y in range(h):
        for x in range(w):
            p = img.get(x, y)
            if p != key:
                canvas.set(x1 + x, y1 + y, p)
```
Information hiding

Humans cannot perceive a small change in light intensity or color value. We can use this to hide information inside images.
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Here is an algorithm to hide a black/white image secret in an image $\text{img}$:

- For all pixels $(r, g, b)$ of $\text{img}$, if $r$ is odd then subtract one from $r$
- For each black pixel of secret, add one to the red value of the same pixel in $\text{img}$. 
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- For each black pixel of secret, add one to the red value of the same pixel in $\text{img}$.

To decode the secret, we look at all pixels $(r, g, b)$ of the image, and turn it black if $r$ is odd, and white otherwise.