Data structures

Inteligencia Artificial en los Sistemas de Control Autónomo
Máster en Ciencia y Tecnología desde el Espacio

Departamento de Automática

Universidad de Alcalá ISG

Objectives

1. Understand the need to store information in data structures.
2. Understand the need to use the type of data structure most appropriate according to data processing to be performed in the script.
3. Know how to use the different types of existing data structure in Python.

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Data structures

Introduction

Programming is about information representation.

- Simple data are easy to represent: Numbers, characters, strings, etc.

Reality uses to be more complicated.

- A class represent an object.
- How can we store several objects?
- How can we represent complex data?

We need powerful mechanisms to store information: Data structures.

Java Collections

Array

Vector (1-D array)

$$\begin{array}{cccc} 0 & 1 & 2 & 3 \\ \hline a_0 & a_1 & a_2 & a_3 \end{array}$$

Matrix (2-D array)

$$\begin{array}{c|cccc} & 0 & 1 & 2 & 3 \\ \hline 0 & a_{0,0} & a_{0,1} & a_{0,2} & a_{0,3} \\ 1 & a_{1,0} & a_{1,1} & a_{1,2} & a_{1,3} \\ 2 & a_{2,0} & a_{2,1} & a_{2,2} & a_{2,3} \end{array}$$

Advantajes:

- Very fast

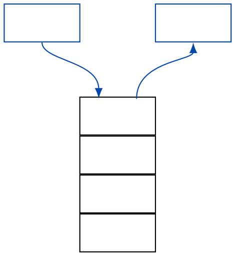
Disadvantajes:

- Fixed size
- Nor supported in Python *by default*

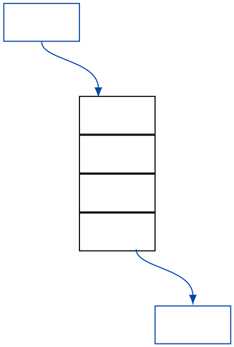
Data structures

Data structures (I): Stack and queue

Stack (LIFO)



Queue (FIFO)



Operations:

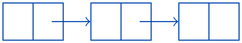
- `push(value)` and `pop(value)`

Implemented as lists in Python

Data structures

Lists and hash tables

Lists



Operations:

- `insert(pos, value)`
- `get(pos)`

Hash table
(associative array, dictionary)

Key 1	Value 1
Key 2	Value 2
Key 3	Value 3
Key 4	Value 4

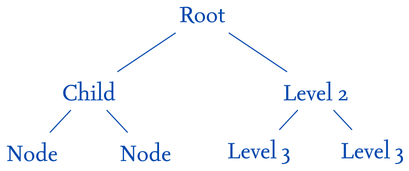
Operations:

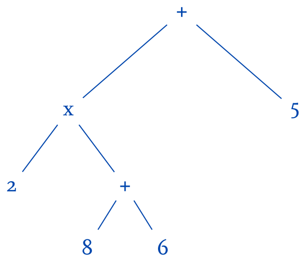
- `put(key, value)`
- `get(key)`

Data structures

Trees (I)

Trees





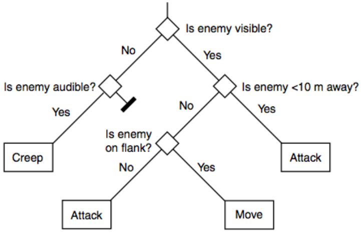
Operations:

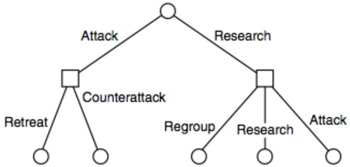
- `insert()` and `remove()`
- `search()`

$$2 * (8 + 6) + 5$$

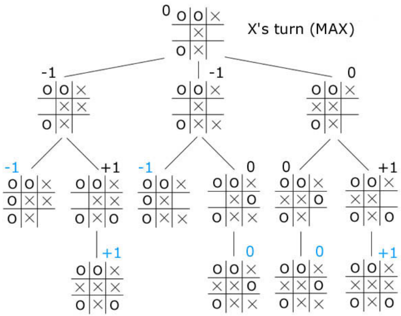
Data structures

Trees (II)





Source: Ian Millington, John Funge. "*Artificial Intelligence for Games*". Ed. Morgan-Kaufmann. 2009.

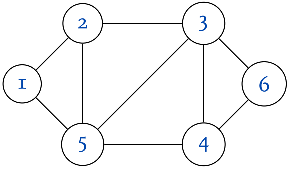


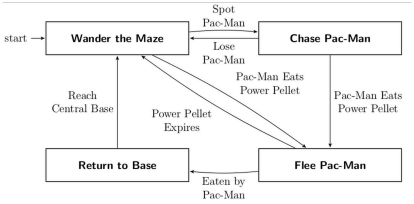
(Source)

Data structures

Graphs

Graphs





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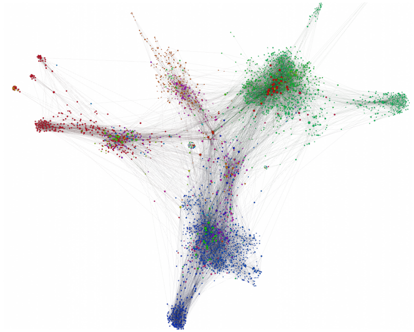

(Source)

(Video Path-Planning)

Data structures in Python

Overview

High-level, language-defined data structures:

- Lists.
- Tuples and sequences.
- Sets.
- Dictionaries (associative arrays).

Data structures in Python

Lists (I)

List initialization

```
list = [item1, ..., itemN]
```

Lists are objects

Methods:

- `list.append(x)`
- `list.insert(i, x)`
- `list.remove(x)`
- `list.pop()`
- `list.index(x)`
- `list.count(x)`
- `list.sort()`
- `list.reverse()`

Data structures in Python

Lists (II)

```
>>> a = [66.25, 333, 333, 1, 1234.5]
>>> print(a.count(333), a.count(66.25), a.count('x'))
2 1 0
>>> a.insert(2, -1)
>>> a.append(333)
>>> a
[66.25, 333, -1, 333, 1, 1234.5, 333]
>>> a.index(333)
1
>>> a.remove(333)
>>> a
[66.25, -1, 333, 1, 1234.5, 333]
>>> a.reverse()
>>> a
[333, 1234.5, 1, 333, -1, 66.25]
>>> a.sort()
>>> a
[-1, 1, 66.25, 333, 333, 1234.5]
```

Data structures in Python

Lists (III)

Slice notation in lists

```
t = [0, 1, 2, 3]
print(t)
print(len(t))
print(t[1])
print(t[1:3])
print(t[2:])
print(t[-1])
print(t[:-1])
print(t[:-3])
print(t[::-1])
```

Data structures in Python

Lists (IV)

Sometimes it is useful to `split` a string to build a list (split) and, conversely, `join` the elements of a list to build a string

join-split.py

```
cadena_ejemplo="Cadena para prueba de join y split"

print (cadena_ejemplo.split())
print ("otra-prueba".split("-"))

con_lista=["Cadena2", "de", "prueba", "de", "join"]

#print (con_lista.join()) # ERROR!
print("".join(con_lista))
print(",".join(con_lista))
```

Data structures in Python

Lists as stacks

Just use two methods: append() and pop()

```
>>> stack = [3, 4, 5]
>>> stack.append(6)
>>> stack.append(7)
>>> stack
[3, 4, 5, 6, 7]
>>> stack.pop()
7
>>> stack
[3, 4, 5, 6]
>>> stack.pop()
6
>>> stack.pop()
5
>>> stack
[3, 4]
```

Data structures in Python

Lists as queues

Queues with lists is not very efficient

- Use instead the `deque` module from the `collections` library.

```
>>> from collections import deque
>>> queue = deque(["Eric", "John", "Michael"])
>>> queue.append("Terry")
>>> queue.append("Graham")
>>> queue.popleft()
'Eric'
>>> queue.popleft()
'John'
>>> queue
deque(['Michael', 'Terry', 'Graham'])
```

New Python feature: Modules

Data structures in Python

The `del` statement

`del` is used to delete items and variables

```
>>> a = [-1, 1, 66.25, 333, 333, 1234.5]
>>> del a[0]
>>> a
[1, 66.25, 333, 333, 1234.5]
>>> del a[2:4]
>>> a
[1, 66.25, 1234.5]
>>> del a[:]
>>> a
[]
>>> del a
>>> a
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  NameError: name 'a' is not defined
```

New Python feature: Error traces

Other data structures in Python

Tuples (I)

Tuple: A sequence of *ordered* items, very similar to lists.

- However they are not the same.
- Lists are *mutable*, tuples are *inmutable*.
- Tuples use to contain, **usually**, heterogeneus items.
- Lists use to contain, **usually**, homogeneus items, used to iterate.
- Lists and tuples are ordered

Creation

```
tup1 = 1, 2, 3
tup2 = ("Hi", 1.1, 2)
tup3 = (0, (1, 3), 2)
```

Manipulation

```
>>> tup1[0]
1
>>> tup1
(1, 2, 3)
>>> tup1[1:]
(2, 3)
```

Other data structures in Python

Tuples (II)

Modification

```
>>> tuple1 = ('a', 'z', 'c')
>>> tuple1[0] = 1
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: 'tuple' object does not support item assignment
>>> tuple1.append('x')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError:'tuple' object has no attribute 'append'
>>> tuple1.index('z')
1
>>> () == True
False
```

Other data structures in Python

Sets (I)

Set: A collection of items, unordered with no duplicates.

- Membership testing.
- Eliminating duplicate entries.
- Math operations: `union()`, `intersection()` and `difference()`.

Creation (I)

```
set1 = {"red", "blue"}
>>> type(set1)
<class 'set'>
>>>  set1 = set()
>>> set1
set1()
>>> what_is = {}
>>> type(what_is)
<class 'dict'>
```

Creation (II)

```
list_mix = ['a', True, 33]
>>> set_mix =  set(list_mix)
>>> set_mix
{'a', True, 33}
>>>  len(set_mix)
3
>>> 33 in set1
True
```

Other data structures in Python

Sets (II). Modification

```
set_mix1 = {'a', 'b'}
>>> set_mix1.add('c')
{'a', 'b', 'c'}
>>> set_mix1.add('a')
>>> set_mix1
{'a', 'b', 'c'}
>>> set_mix1.update({'b', 'c', 'd'}, {'b', 'e', 'a'})
>>> set_mix1
{'a', 'b', 'c', 'd', 'e'}
>>> set_mix1.update(['b', 'c', True])
>>> set_mix1
{'a', 'b', 'c', 'd', 'e', True}
>>> set_mix1.discard(False)
>>> set_mix1
{'a', 'b', 'c', 'd', 'e', True}
```

Other data structures in Python

Sets (III). Modification

```
>>> set_mix1.remove(False)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
KeyError: False
>>> set_mix1.remove(True)
>>> set_mix1
{'a', 'b', 'c', 'd', 'e'}
>>> set_mix1.pop()
'c'
>>> set_mix1
{'a', 'b', 'd', 'e'}
>>> set_mix1.clear()
>>> set_mix1
set()
>>> set_mix1 = {2, 5}
>>> set_mix2 = {1, 2, 3}
>>> set_mix1.union(set_mix2)
{1, 2, 5, 3}
```

Sequence: All types that behaves like sequences: Strings, lists and tuples.

Other data structures in Python

Dictionaries (I)

Dictionary: A collection of pairs `<key, value>`

- Also named as *associative array*, very similar to hash maps.
- Lists are indexed with a number, dictionaries use keys.
- Key: Numbers, strings, tuples and any inmutable type.

Creation

```
>>> tel = {'jack' : 4098, 'sape'
    : 4139 }
>>> tel['guido'] = 4127
>>> tel
{'guido': 4127, 'jack': 4098, '
    sape': 4139}
```

Manipulation

```
>>> del tel['sape']
>>> tel
{'guido': 4127, 'jack': 4098}
>>> list(tel.keys())
['guido', 'jack']
>>> 'guido' in tel
True
```

Other data structures in Python

Dictionaries (II)

Dictionaries can be iterated by key or by value

- Loop syntax is slightly different
- `item()` method

Dictionary iteration

```
knights = {'gallard' : 'the pure', 'robin' : 'the brave'}
for k, v in knights.items():
  print(k, v)
```

Other data structures in Python

Looping techniques (I)

A bunch of useful functions for looping

`enumerate()`	Retrieve position index and value.
`zip()`	Pair two or more sequences.
`sorted()`	Iterate in order.
`reversed()`	Iterate in reverse order.

Other data structures in Python

Looping techniques (II)

enumerate()

```
for i, v in enumerate(['tic', 'tac', 'toe']):
  print(i, v)
```

zip()

```
questions = ['name', 'quest', 'favorite color']
answers = ['lancelot', 'the holy grail', 'blue']

for q, a in zip(questions, answers):
  print('What is your {0}? It is {1}.'.format(q, a))
```

Other data structures in Python

Looping techniques (III)

sorted()

```
basket = ['apple', 'orange', 'apple', 'pear']
for f in sorted(set(basket)):
    print(f)
```

reversed()

```
for i in reversed(range(1, 10, 2)):
    print(i)
```

Other data structures in Python

More on conditions (I)

Comparison operators

==	Equal to
!=	Not equal to
<>	Similar to != (deprecated in 3.x)
>	Greater than
<	Less than
>=	Less or eq. to
<=	Less or eq. to

Conditional operators

`and`	AND
`or`	OR
`not`	Negation

- Widely used in loops and conditions
- Result: `true` or `false`
  - Python supports boolean variables
  - The result is a boolean
- Truth tables represent the conditional operators

Truth tables

A	TTFF
B	TFTF
A and B	TFFF

A	TTFF
B	TFTF
A or B	TTTF

Other data structures in Python

More on conditions (II)

Example

```
value1 = int(input("Give me a number:"))
value2 = int(input("Give me another number:"))

if value1 == value2:
  print("value1 == value2")
else:
  print("value1 != value2")

if value1 > value2:
  print("value1 > value2")
elif value1 < value2:
  print("value1 < value2")
```

Other data structures in Python

More on conditions (III)

Identity operators

`is`	Same objects
`is not`	Not same objects

Membership operators

`in`	Contained
`not in`	Not contained

- Identity operators compare `objects`
  - We will study objects later, do not worry right now
- Membership valid on sequences
  - Remember: A sequence is a string, tuple or list

Example

```
value = int(input("Give me a number between 1 and 5:"))

while value not in range(1, 6):
  value = int(input("Give me a number between 1 and 5:"))
```

Summary

	Mutable	Ordered	Initialization
List	Yes	Yes	`li = [1, 2, 3]`
Tuple	No	Yes	`tu = (1, 2, 3)`
			`tu = 1, 2, 3`
Set	No	No	`se = {1, 2, 3}`
Dictionary	Yes	No	`dic = {'abc' : 1, 'bca' : 2}`