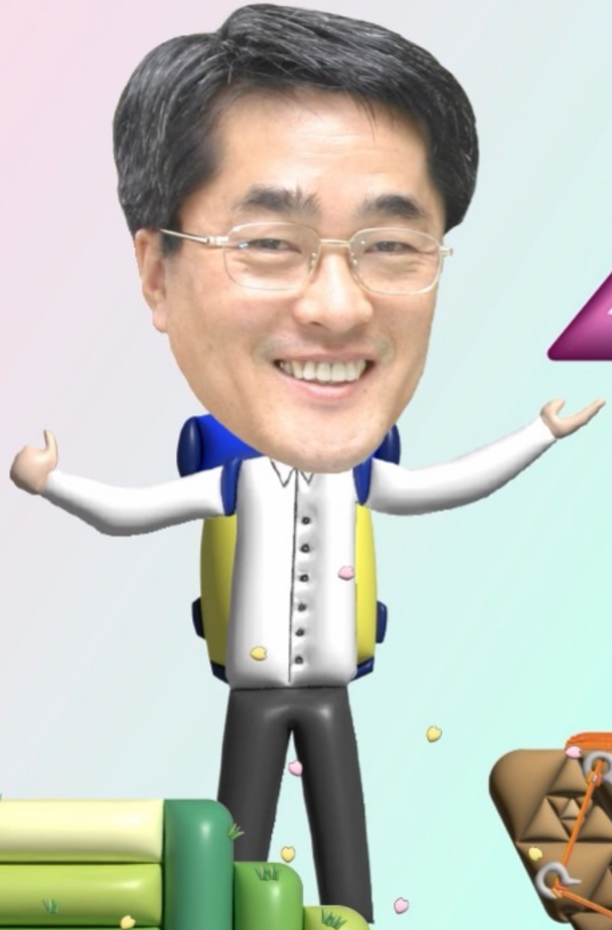
파이썬으로 배우는 데이터 구조



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학습 목표

해시맵(Hashmap)의 ADT를
이해하고 구현할 수 있다

Data Structures in Python
Chapter 6

- Hash Table
- Collision Resolution
- Double Hashing & Rehashing
- **HashMap Coding**

Agenda & Readings

- Hash map Implementation
  - Map Abstract Data Type(ADT)
  - Map ADT Implementation
  - Using the [ ] syntax
  - Using the del Operator

- Reference:
  - Problem Solving with Algorithms and Data Structures
  - Chapter 5 - Hashing

Map Abstract Data Type

- Map data structure:
  - It is a Non-Linear Data Structure which stores data in key-value pairs.
  - The keys are unique, and values can have duplicate entries.
  - It doesn't have any order or sequence like Linked List. Data is stored randomly.

- Examples:
  - Python - Dictionary
  - Java - HashTable, HashMap, LinkedHashMap
  - C++ - map, unordered_map

Map Abstract Data Type

- Operations of a Map ADT:
  - put(key, value)
  - get(key)
  - del map[key]
  - len()
  - in   # contains a given key
- The Python dictionary stores key-value pairs where the key is unique.
  The key is used to look up the associated data value.
  The Python dictionary is an implementation of the Map ADT.
- Example:

```
phone_ext = {'Lee':2410,'Sam':1131,"Pete":2830, "John":1345}
phone_ext["Liz"] = 1123
print('Sam' in phone_ext)
print(phone_ext["John"])
del phone_ext["Sam"]
print(len(phone_ext))
```

```
True
1345
4
```

Map ADT - An Implementation

- We will use two parallel Python lists, one for the slot numbers corresponding to the keys and one for the associated data. We are using linear probing to resolve collisions.
  - Example: The table size is 11 initially; **hash(key) = key % 11**

	0	1	2	3	4	5	6	7	8	9	10
slot	None	None	None	None	None	None	None	None	None	None	None

	0	1	2	3	4	5	6	7	8	9	10
data	None	None	None	None	None	None	None	None	None	None	None

```
ht = HashTable()
ht[54] = "cat"
ht[26] = "dog"
ht[93] = "lion"
ht[17] = "ox"
ht[77] = "bird"
ht[31] = "cow"
ht[44] = "goat"
ht[55] = "pig"
ht[20] = "bear”
```

  - After all the items have been inserted:

	0	1	2	3	4	5	6	7	8	9	10
slot	77	44	55	20	26	93	17	None	None	31	54

	0	1	2	3	4	5	6	7	8	9	10
data	'bird'	'goat'	'pig'	'bear'	'dog'	'lion'	'ox'	None	None	'cow	'cat'

Map ADT - An Implementation

- In this implementation we are using the hash function:

```
def hashfunction(self, key, size):
    return key % size
```

  - Whenever we add an item, we need to call the hash function:

```
hashcode = self.hashfunction(key, len(self.slot))
```

- We will resolve collisions using **linear probing**, i.e., a step size of 1.

```
def rehash(self, old_hash, size):
    return (old_hash + 1) % size
```

  - Whenever there is a collision, we need to get the next slot to try:

```
nextslot = self.rehash(nextslot, size)
```

Map ADT - An Implementation

- Create the two Python lists and set the size of the mapping:

```
class HashTable:
    def __init__(self):
        self.size = 11
        self.slot = [None] * self.size
        self.data = [None] * self.size

        #define the get() and put() methods
        ...

        def hashfunction(self, key, size):
            return key % size

        def rehash(self, old_hash, size):
            return (old_hash + 1) % size
```

```
put(key, value)
get(key)
del map[key]
len()
in      #contains
```

Map ADT - An Implementation

- Getting the associated value of an entry in the hash table:

```
def get(self, key):
    startslot = self.hashfunction(key, len(self.slot))
    position = startslot

    while self.slot[position] != None:
        if self.slot[position] == key:      # key found
            return self.data[position]      # return associated data
        else:
            position = self.rehash(position, len(self.slot))
            if position == startslot:        # all slots in hash table searched
                return None                  # key not in table
    return None                              # empty slot – key not in table
```

```
put(key, value)
get(key)
del map[key]
len()
in      #contains
```

Map ADT - An Implementation

- Putting an entry (key-value pair) into the hash table:

```
def put(self, key, data):
    hashcode = self.hashfunction(key, len(self.slot))
    if self.slot[hashcode] == None:
        self.slot[hashcode] = key          # Put the key and associated data into
        self.data[hashcode] = data         # the lists
    elif self.slot[hashcode] == key:
        self.data[hashcode] = data         # Replace the associated data
    else:
        nextslot = self.rehash(hashcode, len(self.slot))
        while self.slot[nextslot] != None and self.slot[nextslot] != key:
            nextslot = self.rehash(nextslot, len(self.slot))
            if nextslot == hashcode: # Hash table full, cannot add data
                return None
        if self.slot[nextslot] == None:     # Put the key and associated data into
            self.slot[nextslot] = key       # the lists
            self.data[nextslot] = data
        else:
            self.data[nextslot] = data     # Replace the associated data
```

Map ADT - An Implementation

- Similar to the Python dictionary data type, we want to allow applications to use the special [ ] syntax, i.e.:
  - To assign a new mapping: **`ht[54] = "cat"`**
  - To access the associated value in a mapping: **`value = ht[54]`**

```
def __setitem__(self, key, data):
    self.put(key, data)              #refers to the put() method

def __getitem__(self, key):
    return self.get(key)             #refers to the get() method
```

Map ADT - An Implementation

- The implementation now allows the use of the [ ] syntax.

```
class HashTable:
    def __init__(self):
        self.size = 11
        self.slot = [None] * self.size
        self.data = [None] * self.size

    def put(self, key, data):
    ...
    def get(self, key):
    ...

    def __setitem__(self, key, data):
        self.put(key, data)      #refers to the put() method

    def __getitem__(self, key):
        self.get(key)            #refers to the get() method
```

```
ht = HashTable()
ht[54] = "cat"
print(ht[54])
```

HashTable - Deleting a key-value pair

- Deleting a value is non-trivial because of collisions (see next slides).
- **Case 1: key is NOT in the table:**
  - Apply hash function. The slot is either 'None'(we can return) or occupied by another key. If occupied, we look sequentially(linear probing) until we find an element which is 'None'.
  - **Example:** Find **hash[23] -** we apply the hash function h(k)%11, and look in slot 1, then in slots 2, 3, 4, 5, 6, 7. Since slot 7 is 'None' we know the key 23 is not in the table and we do not need to look any further.

	0	1	2	3	4	5	6	7	8	9	10
slot	77	44	55	20	26	93	17	None	None	31	54

	0	1	2	3	4	5	6	7	8	9	10
data	'bird'	'goat'	'pig'	'bear'	'dog'	'lion'	'ox'	None	None	'cow	'cat'

HashTable - Deleting a key-value pair

- Deleting a value is non-trivial because of collisions (see next slides).
- **Case 2: key is in the table:**
  - Assume we wish to delete **hash[55].** We apply the hash function and look in slot 0 (since 55%11 = 0), then we look in slots 1, 2. We find key 55 at 2 and delete it.

	0	1	2	3	4	5	6	7	8	9	10
slot	77	44	55 None	20	26	93	17	None	None	31	54

	0	1	2	3	4	5	6	7	8	9	10
data	'bird'	'goat'	None	'bear'	'dog'	'lion'	'ox'	None	None	'cow	'cat'

  - **Now, what happens if we now wish to find key 20?** (20%11=9)
    Because of collisions it **has been inserted into slot 3**.
    But because slot 2 is now empty **(after deleting 55),** we **cannot** find key 20 anymore.

HashTable - Deleting a key-value pair

- We will need to use a dummy value for elements which have been deleted. In the constructor we can set `self.deleted` to be the `'\0'` null character.

```
class HashTable:
    def __init__(self):
        self.size = 11
        self.slot = [None] * self.size
        self.data = [None] * self.size
        self.deleted = '\0'
```

HashTable - Deleting a key-value pair

- Let us code the delete() method to use "self.deleted" to indicate the deletion:

```
def delete(self, key):
    startslot = self.hashfunction(key, len(self.slot))
    position = startslot
    key_in_slot = self.slot[position]

    while key_in_slot != None:
        if key_in_slot == key:
            self.slot[position] = self.deleted
            self.data[position] = self.deleted
            return None
        else:
            position = self.rehash(position, len(self.slot))
            key_in_slot = self.slot[position]
            if position == startslot:
                return None
```

```
continue to search even if the
slot contains self.deleted.
Only stops if slot is None.
```

```
Key not in table – do nothing
and return
```

HashTable - Deleting a key-value pair

- The __delitem__(⋯) allows the use of the del operator.

```
def delete(self, key):
    ... # see previous slide

def __delitem__(self, key):
    return self.delete(key)
```

```
ht = HashTable()
ht[54] = "cat"
ht[31] = "cow"
ht[44] = "goat"
del ht[44]
del ht[54]
```

HashTable - Updating put() function

- The **put() function** needs to be updated to take into account **self.deleted**

```
def put(self,key,data):
    hashcode = self.hashfunction(key,len(self.slot))
    if self.slot[hashcode] == None or self.slot[hashcode] == self.deleted:
        self.slot[hashcode] = key
        self.data[hashcode] = data
    elif self.slot[hashcode] == key:
        self.data[hashcode] = data
    else:
        nextslot = self.rehash(hashcode, len(self.slot))
        while self.slot[nextslot] != None \
              and self.slot[nextslot] != key: \
              and self.slot[nextslot] != self.deleted
        nextslot = self.rehash(nextslot,len(self.slot))
        if nextslot == hashcode: return
        if self.slot[nextslot] == None or self.slot[nextslot] == self.deleted:
            self.slot[nextslot] = key
            self.data[nextslot] = data
        else:
            self.data[nextslot] = data
```

There is a **bug** in this code.

The 'in' and 'len' Operators

- The __len__(⋯) allows the use of the **len** operator.
  The __contains__(⋯) allows the use of the **in** operator.

```
def __len__(self):
    count = 0
    for value in self.slot:
        if value != None and value != self.deleted:
            count += 1
    return count

def __contains__(self, key):
    return self.get(key) != None
```

Hashing Analysis

- The time complexity of search, insertion, and deletion operations of a hash map is constant time, that is, O(1).

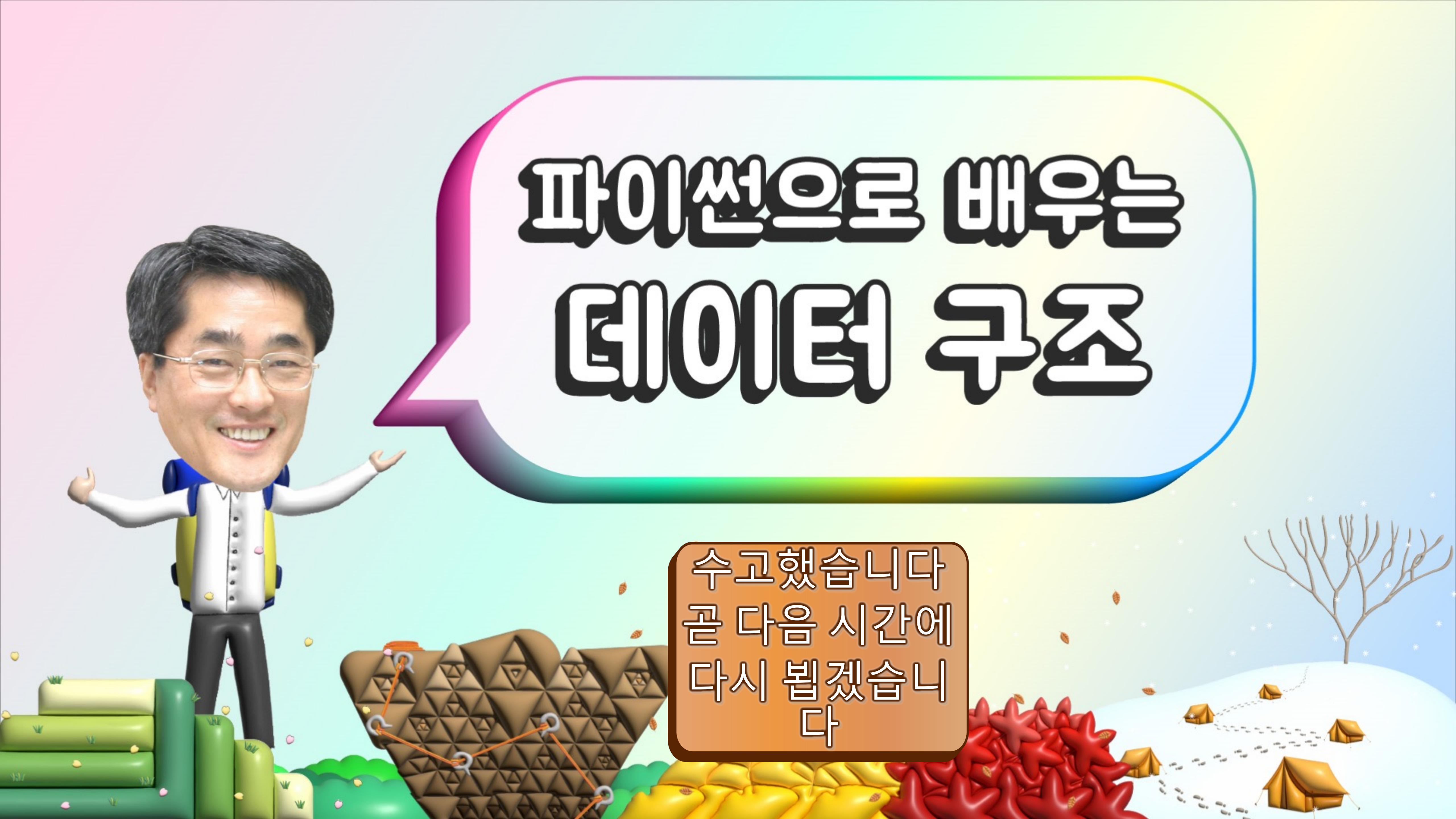
- It must keep the load factor λ small to maintain the time complexity of O(1).

- Hashing provides a useful data structures like hash table, hash map.

학습 정리

1) __setitem__, __getitem__ 을 재정의함으로 대괄호를([ ])를 사용하여 인덱싱할 수 있다

2) 해시맵에서 노드를 삭제하려고 할 때, None과 deleted 값을 가진 노드들을 유의해야한다.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곧 다음 시간에
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