Algorithms and Data Structures

B7. ADTs Map and Set

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Introduction

Reminder: Abstract Data Type

Abstract Data Type

Description of a data type, summarizing the possible data and the possible operations on this data.

- User perspective: How can I use the data type?
- In contrast to data structures, not specifying the concrete representation of the data.

Previous ADTs

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- Stacks
- Queues
- Priority Queues

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- A dynamic set in computer science is slightly different.
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  - Finite.
  - Entries (keys) can sometimes be associated with satellite data.
- Now: Two ADTs for dynamic sets:
  - Map
  - Set

Map

Map

A map stores (key, value) pairs such that each possible key occurs at most once in the collection. It supports the following operations:

- Insert a given key and value. If the key is already present, update the associated value.
- Remove the entry for a given key.
- Lookup the entry for a given key (or return that there is none).

Also known as associative array, dictionary or symbol table.
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Similar to arrays, but using keys instead of indices.

Question (Slido)

What data structure(s) could you use to implement a map?

Map: Data Structures and Running Times

The following data structures can easily be adapted to implement maps:

data structure	insertion	removal or lookup
	avg./worst	avg./worst
linked list	$O(1)/O(1)$	$O(n)/O(n)$
hash table	$O(1)/O(n)$	$O(1)/O(n)$
binary search tree	$O(\log n)/O(n)$	$O(\log n)/O(n)$
red-black tree	$O(\log n)/O(\log n)$	$O(\log n)/O(\log n)$

Maps in Java and Python

Java:

- Interface `Map`
- For example implemented by `HashMap` (hash table) and `TreeMap` (red-black tree).

```
Map<String, Integer> map = new TreeMap<>();
map.put("a key", 42);;
map.put("another key", 17)
Integer value = map.get("aKey");
```

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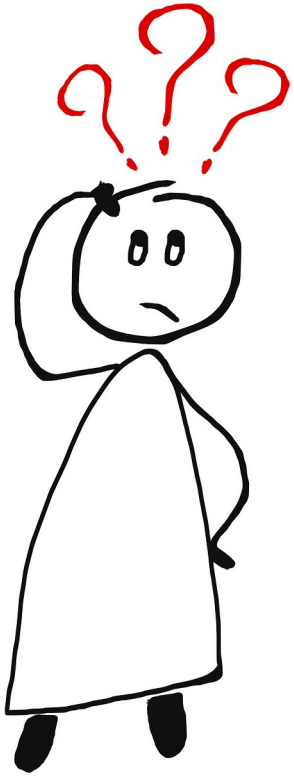
Python:

- Built-in `dict` (hash table)

```python
map = dict()
map["a key"] = 42
map["another key"] = 17
# or alternatively:
# map = {"a key" : 42, "another key" : 17}
value = map["a key"]
```

Questions



Questions?

Set

Set

A set stores keys such that each possible key occurs at most once in the collection. It supports the following operations:

- Insert a given key into a set (if it is not already included).
- Remove the given key from a set.
- Lookup whether a given key is in a set.
- Iteration over all elements of a set in an arbitrary order.

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- Iteration over all elements of a set in an arbitrary order.

In addition, there is often support for the following operators:

- Union of two sets.
- Intersection of two sets.
- Difference of two sets.

Exact names of operations can differ.

Data Structures

We can use the same data structures for sets as for maps.

- Do not store a value with the key.
- Implementation of operators union, intersection can be done based on the core operations or with highly specialized algorithms:
  - E.g., union, intersection and difference possible in $O(m \log(\frac{n}{m} + 1))$ for two red-black trees of sizes m and n (where $m \leq n$).

Sets in Java

Java:

- Interface `Set`
- For example implemented by `HashSet` (based on hash table) and `TreeSet` (based on red-black tree).

```
Set<Integer> nums1 = new HashSet<>();
Set<Integer> nums2 = new HashSet<>();
nums1.add(42);
nums1.add(17);
nums2.add(42);
nums2.add(13);
nums2.add(19);
nums2.remove(13);
nums1.retainAll(nums2); // intersection
if (nums1.contains(42)) {
  System.out.println("Found 42");
}
```

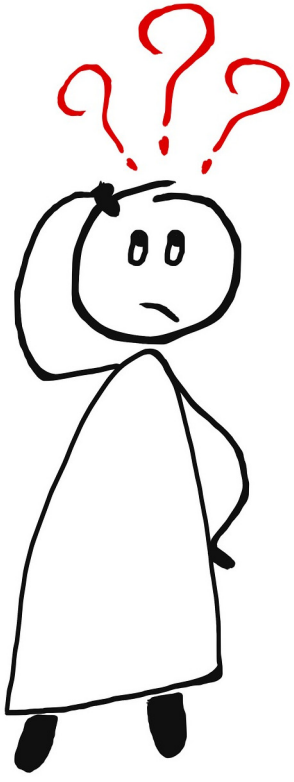
Sets in Python

Python:

- Built-ins `set` and `frozenset` (both based on hash tables; frozen sets are immutable and hashable)

```
s1 = set()
s1.add(42)
s1.add(17)
s2 = {42, 13, 19}
s2.remove(13)
s1 &= s2 # intersection
if 42 in s1:
    print("Found 42")
```

Questions



Questions?

Summary

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- Maps and sets are abstract data types for dynamic sets.
  - Maps map keys to their associated values.
  - Sets only store elements.
  - Both are typically implemented based on hash tables or balanced trees (such as red-black trees).