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BERN

Sets and Maps

Lecturer: **Nataliia Stulova**
Teaching assistant: **Mohammadreza Hazirprasand**

MASTER IN COMPUTER SCIENCE
OF THE UNIVERSITIES OF BERN, NEUCHÂTEL AND FRIBOURG

Software Skills Lab

Recap on data structure properties

Restrictions on element values:

- usually none:
  - Arrays, Lists, Stacks, Queues
- duplicates allowed:
  - Graphs, General trees*
- absence of duplicates:
  - Binary search tree

Element access:

- **fast** - random (by index)
- **slow** - sequential (by iteration or following element links)

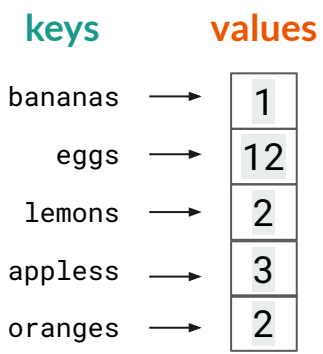
New today: *key-value pairs (Maps)*

Continued today: *treating duplicated elements (Sets)*

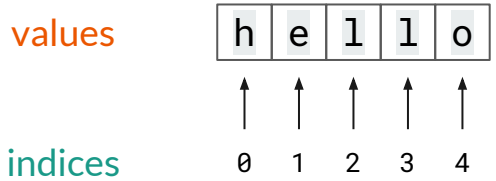
Maps

Map data structure

A data structure composed of ***(key, value) pairs***, such that each possible key appears at most once in the collection:



Compare: “regular” array (keys are element indices, unique!)



Other names: an associative array, symbol table, or dictionary

Map examples

- postal indices
- word dictionaries
- software configuration files
- ....

Use whenever you need to represent data as a tuple or simple structure and one of the fields holds unique values and can be used as a key

JSON format:

```
{ "firstName": "John",
  "lastName": "Smith",
  "isAlive": true,
  "age": 27,
  "address": {
    "streetAddress": "21 2nd Street",
    "city": "New York",
    "state": "NY",
    "postalCode": "10021-3100"
  },
  "children": [],
  "spouse": null
}
```

Map operations

- **add** a pair to the collection
- **remove** a pair from the collection
- **modify** an existing value
- **lookup a value by the key**

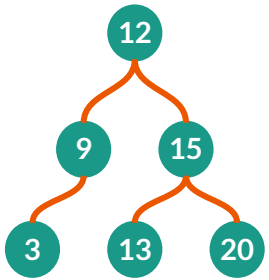
Q: how to do lookup efficiently?

Map operations

- **add** a pair to the collection
- **remove** a pair from the collection
- **modify** an existing value
- **lookup a value by the key**

option 1: search tree (previous lecture)

Q: how to do lookup efficiently?



key,value
3,three
9,nine
13,thirteen
...

keys need to be **comparable**

Map operations

- **add** a pair to the collection
- **remove** a pair from the collection
- **modify** an existing value
- **lookup a value by the key**

option 2: **hash table**

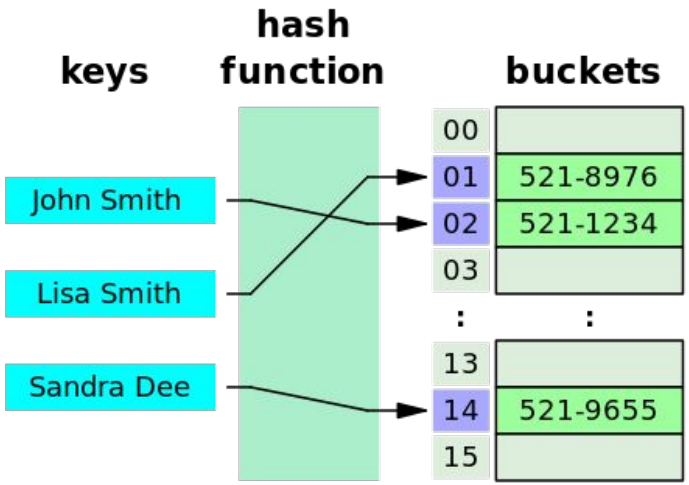
Q: how to do lookup efficiently?

Hash table

hash function computes an index (a hash code), into an array of buckets (slots)

since hash function values are comparable - keys themselves do not have to be such!

E.g.: would you order by name, initials…?



credit: Wikipedia

java.util.Map

Reference javadoc: Map (Java SE 11 & JDK 11)

A library **interface** `Map<K,V>` that provides various useful operations on maps:

- `containsKey()`
- `containsValue()`
- `get()`
- `put()`
- `remove()`
- `replace()`
- `keySet()`
- `values()`

Map **classes** implementing this interface:

- `HashMap<K,V>`
- `TreeMap<K,V>`
- `Hashtable<K,V>`
- `LinkedHashMap<K,V>`
- `...`

pay attention to: iteration order,
nullness of keys and values (allowed or not)

Sets

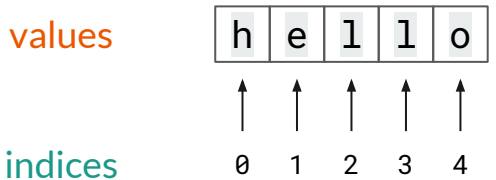
Set data structure

A data structure composed of **unique *values:***

- no ordering of the elements
- no duplication of elements

Use whenever you need to check if a value belongs to a set, or you need to reason about several collections of values: filter duplicates, count unique values….

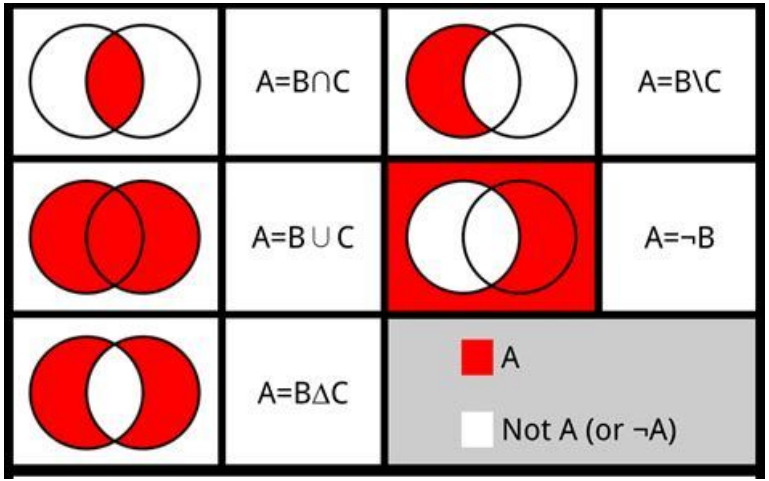
Compare: “regular” array



Respective **set**: `{h,e,l,o}`

Set operations

- intersection
- union
- symmetric difference
- difference
- complement



credit: Wikipedia

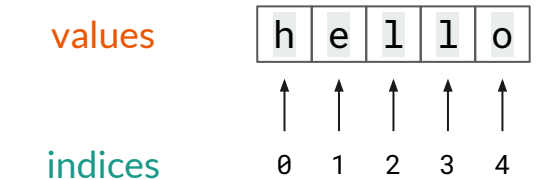
Multiset, or Bag

Bag data structure allows duplicates - and stores them as counts.

Uses:

- databases (SQL query results)
- NLP: stop words filtering, text similarity computation

Compare: “regular” array



Respective **bag**:

`{1:h, 1:e, 2:l, 1:o}`

java.util.Set

Reference javadoc: Set (Java SE 11 & JDK 11)

A library **interface** `Set<E>` that provides various useful operations on sets:

- `contains()`
- `add()`
- `remove()`
- …

There are classes implementing sets in Java SE

pay attention to: iteration order,
nullness of keys and values (allowed or not)

For multisets see third-party libraries:

- Apache Commons
- Google Guava

Practice

Exercise 1

associative array - abbreviation expansion

- read a CSV file (5-6 lines)
- in each line first word is a key, second is a value:

```
WHO,World Health Organization
BBC,British Broadcasting Corporation
```

- use 2-3 different Map implementations to store this data
- print out tuples: as you add and as you iterate, compare the order

I/O

- Input: File IO for reading data
- Output: Stream IO to print

Tests

-

Exercise 2

word counts and multisets

- read a sentence, split on whitespace to get words
- add words to a bag
- print 3 words that occur most often

I/O

- Input: manual or System.in
- Output: System.out to print output

Tests

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