CSE 143
Lecture 14 (B)

Maps and Grammars

reading: 11.3

slides created by Marty Stepp
http://www.cs.washington.edu/143/

Exercise

- Write a program to count the occurrences of each word in a large text file (e.g. *Moby Dick* or the King James Bible).

  - Allow the user to type a word and report how many times that word appeared in the book.

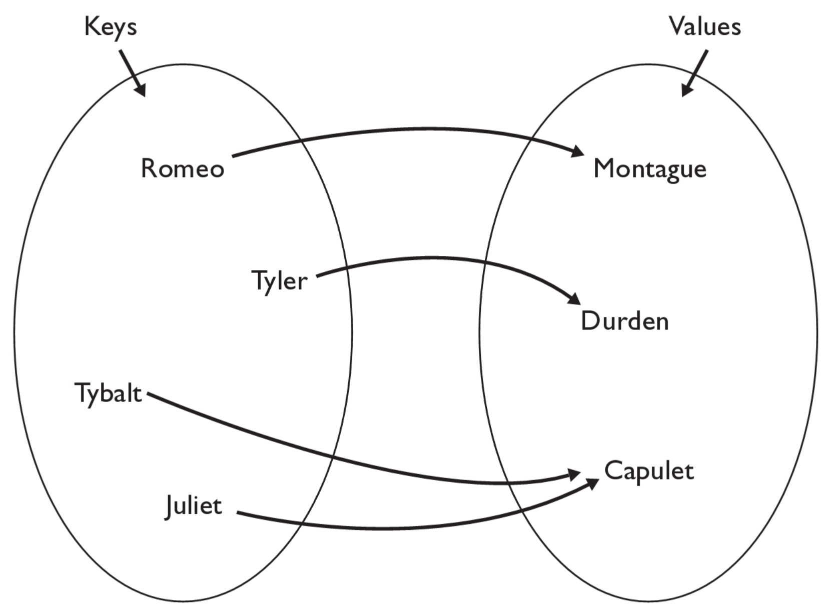
  - Report all words that appeared in the book at least 500 times, in alphabetical order.

- How will we store the data to solve this problem?

The Map ADT

- **map**: Holds a set of unique *keys* and a collection of *values*, where each key is associated with one value.
  - a.k.a. "dictionary", "associative array", "hash"

- basic map operations:
  - **put**(*key*, *value*): Adds a mapping from a key to a value.
  - **get**(*key*): Retrieves the value mapped to the key.
  - **remove**(*key*): Removes the given key and its mapped value.



`myMap.get("Juliet")` returns `"Capulet"`

Maps and tallying

- a map can be thought of as generalization of a tallying array
  - the "index" (key) doesn't have to be an `int`

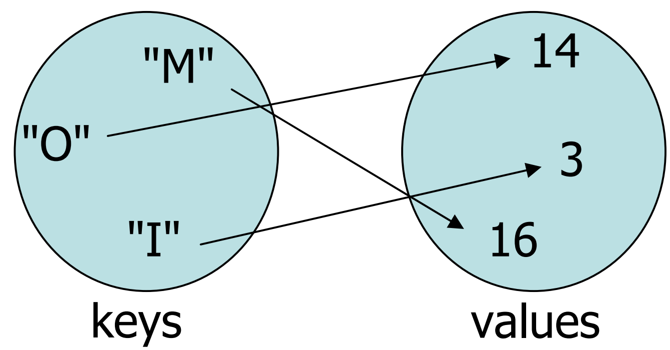
- recall previous tallying examples from CSE 142
  - count digits: `22092310907`

index	0	1	2	3	4	5	6	7	8	9
value	3	1	3	0	0	0	0	1	0	2

```
// (M)cCain, (O)bama, (I)ndependent
```

  - count votes: `"MOOOOOMMMMOOOOOOMOMMIMOMMIMOMMIO"`

key	"M"	"O"	"I"
value	16	14	3



Map implementation

- in Java, maps are represented by Map interface in java.util

- Map is implemented by the HashMap and TreeMap classes
  - HashMap: implemented using an array called a "hash table"; extremely fast: **O(1)** ; keys are stored in unpredictable order
  - TreeMap: implemented as a linked "binary tree" structure; very fast: **O(log N)** ; keys are stored in sorted order

  - A map requires 2 type parameters: one for keys, one for values.

```
// maps from String keys to Integer values
Map<String, Integer> votes = new HashMap<String, Integer>();
```

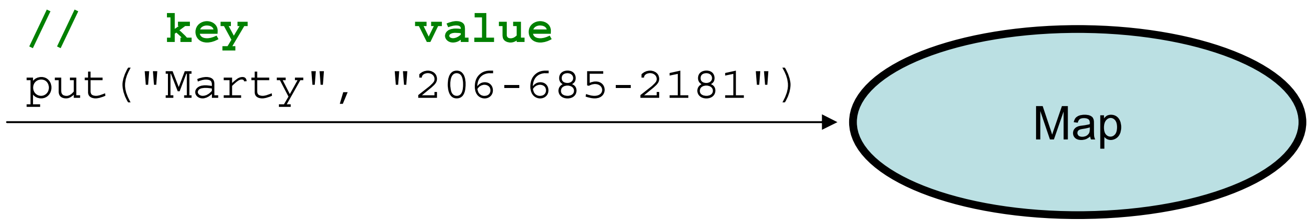
`Map` methods

`put(`**key**`, `**value**`)`	adds a mapping from the given key to the given value; if the key already exists, replaces its value with the given one
`get(`**key**`)`	returns the value mapped to the given key (`null` if not found)
`containsKey(`**key**`)`	returns `true` if the map contains a mapping for the given key
`remove(`**key**`)`	removes any existing mapping for the given key
`clear()`	removes all key/value pairs from the map
`size()`	returns the number of key/value pairs in the map
`isEmpty()`	returns `true` if the map's size is 0
`toString()`	returns a string such as `"{a=90, d=60, c=70}"`

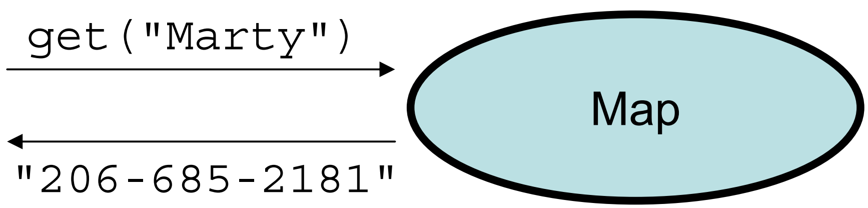
`keySet()`	returns a set of all keys in the map
`values()`	returns a collection of all values in the map
`putAll(`**map**`)`	adds all key/value pairs from the given map to this map
`equals(`**map**`)`	returns `true` if given map has the same mappings as this one

Using maps

- A map allows you to get from one half of a pair to the other.
  - Remembers one piece of information about every index (key).



  - Later, we can supply only the key and get back the related value:
    Allows us to ask: *What is Marty's phone number?*



Exercise solution

```
// read file into a map of [word --> number of occurrences]
Map<String, Integer> wordCount = new HashMap<String, Integer>();
Scanner input = new Scanner(new File("mobydick.txt"));
while (input.hasNext()) {
    String word = input.next();
    if (wordCount.containsKey(word)) {
        // seen this word before; increase count by 1
        int count = wordCount.get(word);
        wordCount.put(word, count + 1);
    } else {
        // never seen this word before
        wordCount.put(word, 1);
    }
}

Scanner console = new Scanner(System.in);
System.out.print("Word to search for? ");
String word = console.next();
System.out.println("appears " + wordCount.get(word) + " times.");
```

`keySet` and `values`

- `keySet` method returns a set of all keys in the map
  - can loop over the keys in a foreach loop
  - can get each key's associated value by calling `get` on the map

```
Map<String, Integer> ages = new HashMap<String, Integer>();
ages.put("Marty", 19);
ages.put("Geneva", 2);
ages.put("Vicki", 57);
for (String name : ages.keySet()) {             // Geneva -> 2
    int age = ages.get(age);                    // Marty -> 19
    System.out.println(name + " -> " + age);    // Vicki -> 57
}
```

- `values` method returns a collection of all values in the map
  - can loop over the values in a foreach loop
  - there is no easy way to get from a value to its associated key(s)

Languages and Grammars

Languages and grammars

- (formal) **language**: A set of words or symbols.

- **grammar**: A description of a language that describes which sequences of symbols are allowed in that language.
  - describes language *syntax* (rules) but not *semantics* (meaning)
  - can be used to generate strings from a language, or to determine whether a given string belongs to a given language

Backus-Naur (BNF)

- **Backus-Naur Form (BNF)**: A syntax for describing language grammars in terms of transformation *rules*, of the form:

  <**symbol**> ::= <**expression**> | <**expression**> ... | <**expression**>

  - **terminal**: A fundamental symbol of the language.
  - **non-terminal**: A high-level symbol describing language syntax, which can be transformed into other non-terminal or terminal symbol(s) based on the rules of the grammar.

  - developed by two Turing-award-winning computer scientists in 1960 to describe their new ALGOL programming language

An example BNF grammar

```
<s>::=<n> <v>
<n>::=Marty | Victoria | Stuart | Jessica
<v>::=cried | slept | belched
```

- Some sentences that could be generated from this grammar:

```
Marty slept
Jessica belched
Stuart cried
```

BNF grammar version 2

```
<s>::=<np> <v>
<np>::=<pn> | <dp> <n>
<pn>::=Marty | Victoria | Stuart | Jessica
<dp>::=a | the
<n>::=ball | hamster | carrot | computer
<v>::=cried | slept | belched
```

- Some sentences that could be generated from this grammar:

```
the carrot cried
Jessica belched
a computer slept
```

BNF grammar version 3

```
<s>::=<np> <v>
<np>::=<pn> | <dp> <adj> <n>
<pn>::=Marty | Victoria | Stuart | Jessica
<dp>::=a | the
<adj>::=silly | invisible | loud | romantic
<n>::=ball | hamster | carrot | computer
<v>::=cried | slept | belched
```

- Some sentences that could be generated from this grammar:

```
the invisible carrot cried
Jessica belched
a computer slept
a romantic ball belched
```

Grammars and recursion

```
<s>::=<np> <v>
<np>::=<pn> | <dp> <adjp> <n>
<pn>::=Marty | Victoria | Stuart | Jessica
<dp>::=a | the
<adjp>::=<adj> <adjp> | <adj>
<adj>::=silly | invisible | loud | romantic
<n>::=ball | hamster | carrot | computer
<v>::=cried | slept | belched
```

- Grammar rules can be defined *recursively*, so that the expansion of a symbol can contain that same symbol.
  - There must also be expressions that expand the symbol into something non-recursive, so that the recursion eventually ends.

Grammar, final version

```
<s>::=<np> <vp>
<np>::=<dp> <adjp> <n>|<pn>
<dp>::=the|a
<adjp>::=<adj>|<adj> <adjp>
<adj>::=big|fat|green|wonderful|faulty|subliminal
<n>::=dog|cat|man|university|father|mother|child
<pn>::=John|Jane|Sally|Spot|Fred|Elmo
<vp>::=<tv> <np>|<iv>
<tv>::=hit|honored|kissed|helped
<iv>::=died|collapsed|laughed|wept
```

- Could this grammar generate the following sentences?

```
Fred honored the green wonderful child
big Jane wept the fat man fat
```

- Generate a random sentence using this grammar.

Sentence generation