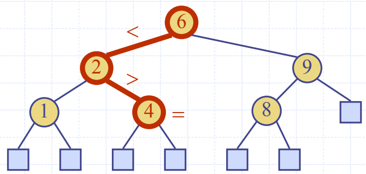
Dictionaries



Dictionary ADT (§ 8.3)

- The dictionary ADT models a searchable collection of key-element entries
- The main operations of a dictionary are searching, inserting, and deleting items
- Multiple items with the same key **are** allowed
- Applications:
  - word-definition pairs
  - credit card authorizations
  - DNS mapping of host names (e.g., datastructures.net) to internet IP addresses (e.g., 128.148.34.101)
- Dictionary ADT methods:
  - find(k): if the dictionary has an entry with key k, returns it, else, returns null
  - findAll(k): returns an iterator of all entries with key k
  - insert(k, o): inserts and returns the entry (k, o)
  - remove(e): remove the entry e from the dictionary
  - entries(): returns an iterator of the entries in the dictionary
  - size(), isEmpty()

Example

Operation	***Output***	***Dictionary***
insert(5,*A*)	(5,*A*)	(5,*A*)
insert(7,*B*)	(7,*B*)	(5,*A*),(7,*B*)
insert(2,*C*)	(2,*C*)	(5,*A*),(7,*B*),(2,*C*)
insert(8,*D*)	(8,*D*)	(5,*A*),(7,*B*),(2,*C*),(8,*D*)
insert(2,*E*)	(2,*E*)	(5,*A*),(7,*B*),(2,*C*),(8,*D*),(2,*E*)
find(7)	(7,*B*)	(5,*A*),(7,*B*),(2,*C*),(8,*D*),(2,*E*)
find(4)	**null**	(5,*A*),(7,*B*),(2,*C*),(8,*D*),(2,*E*)
find(2)	(2,*C*)	(5,*A*),(7,*B*),(2,*C*),(8,*D*),(2,*E*)
findAll(2)	(2,*C*),(2,*E*)	(5,*A*),(7,*B*),(2,*C*),(8,*D*),(2,*E*)
size()	5	(5,*A*),(7,*B*),(2,*C*),(8,*D*),(2,*E*)
remove(find(5))	(5,*A*)	(7,*B*),(2,*C*),(8,*D*),(2,*E*)
find(5)	**null**	(7,*B*),(2,*C*),(8,*D*),(2,*E*)

A List-Based Dictionary

- A log file or audit trail is a dictionary implemented by means of an unsorted sequence
  - We store the items of the dictionary in a sequence (based on a doubly-linked list or array), in arbitrary order
- Performance:
  - insert takes $O(1)$ time since we can insert the new item at the beginning or at the end of the sequence
  - find and remove take $O(n)$ time since in the worst case (the item is not found) we traverse the entire sequence to look for an item with the given key
- The log file is effective only for dictionaries of small size or for dictionaries on which insertions are the most common operations, while searches and removals are rarely performed (e.g., historical record of logins to a workstation)

The findAll(k) Algorithm

Algorithm findAll(*k*):
Input: A key *k*
Output: An iterator of entries with key equal to *k*

```
Create an initially empty list L
B = D.entries()
while B.hasNext() do
    e = B.next()
    if e.key() = k then
        L.insertLast(e)
return L.elements()
```


The insert and remove Methods

Algorithm insert(*k*,*v*):
Input: A key *k* and value *v*
Output: The entry (*k*,*v*) added to *D*

```
Create a new entry e = (k,v)
S.insertLast(e)        {S is unordered}
return e
```

Algorithm remove(*e*):
Input: An entry *e*
Output: The removed entry *e* or **null** if *e* was not in *D*

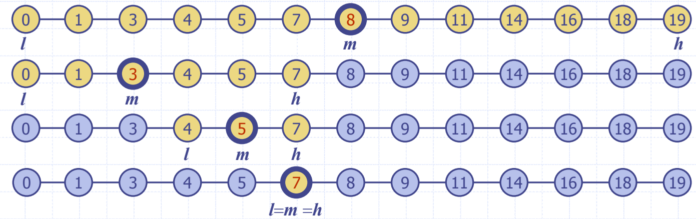
```
{We don't assume here that e stores its location in S}
B = S.positions()
while B.hasNext() do
    p = B.next()
    if p.element() = e then
        S.remove(p)
        return e
return null        {there is no entry e in D}
```


Hash Table Implementation

- We can also create a hash-table dictionary implementation.
- If we use separate chaining to handle collisions, then each operation can be delegated to a list-based dictionary stored at each hash table cell.

Binary Search

- Binary search performs operation find(k) on a dictionary implemented by means of an array-based sequence, sorted by key
  - similar to the high-low game
  - at each step, the number of candidate items is halved
  - terminates after a logarithmic number of steps
- Example: find(7)



Search Table

- A search table is a dictionary implemented by means of a sorted array
  - We store the items of the dictionary in an array-based sequence, sorted by key
  - We use an external comparator for the keys
- Performance:
  - find takes $O(\log n)$ time, using binary search
  - insert takes $O(n)$ time since in the worst case we have to shift $n/2$ items to make room for the new item
  - remove takes $O(n)$ time since in the worst case we have to shift $n/2$ items to compact the items after the removal
- A search table is effective only for dictionaries of small size or for dictionaries on which searches are the most common operations, while insertions and removals are rarely performed (e.g., credit card authorizations)