CMSC 132: Object-Oriented Programming II

Hashing

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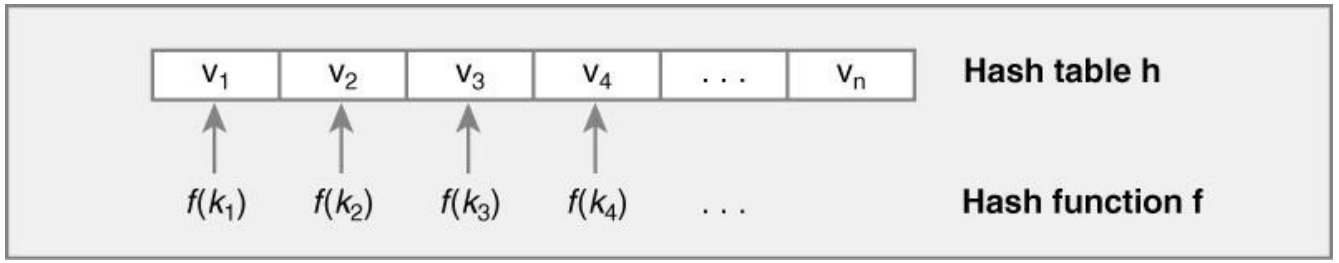
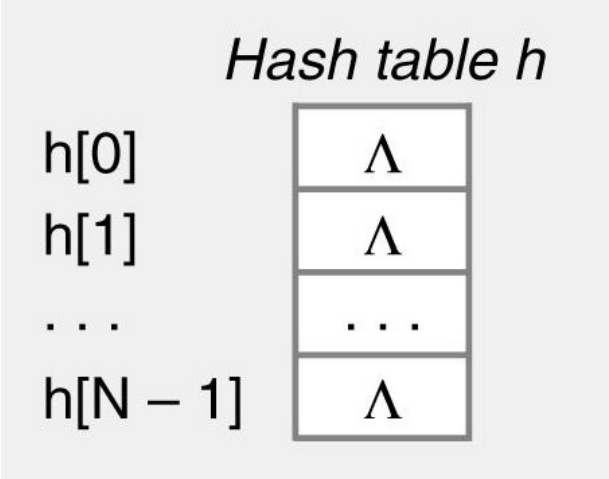
Hashing

- **Hashing**
  - Hashing function → function that maps data to a value (e.g., integer)
  - Hash Code/Hash Value → value returned by a hash function
  - Hash functions can be used to speed up data access
  - We can achieve O(1) data access using hashing
- **Approach**
  - Use hash function to convert key into number (hash value) used as index in hash table



Hashing

- Hash Table
  - Array indexed using hash values
  - Hash table A with size N
  - Indices of A range from 0 to N-1
  - Store in A[hashValue % N]



Location	Key
0	Λ
1	10
2	15
3	20
4	Λ
. . .	

Hash Function

- Hash Function → Function for converting key into hash value
- For hash table of size N
  - Must reduce hash value to 0..N – 1
  - Can use modulo operator → hash value = Math.abs(keyValue % N)
- Example Problem
  - Assign 4 parking spaces to 4 people using
    - h(key) = keyValue % 4
  - What happens if we have 4 spaces and 8 people?
    - Collision → Same hash value for multiple keys
- Bucket
  - Each table entry can be referred to as a bucket
  - In some implementations the bucket is represented by a list (those elements hashing to the same bucket are placed in the same list)
- Properties of a Good Hash Function
  - Distributes (scatters) values uniformly across range of possible values
  - It is not expensive to compute

Hash Function

- **Example**

  hash("apple") = 5
  hash("watermelon") = 3
  hash("grapes") = 8
  hash("kiwi") = 0
  hash("strawberry") = 9
  hash("mango") = 6
  hash("banana") = 2

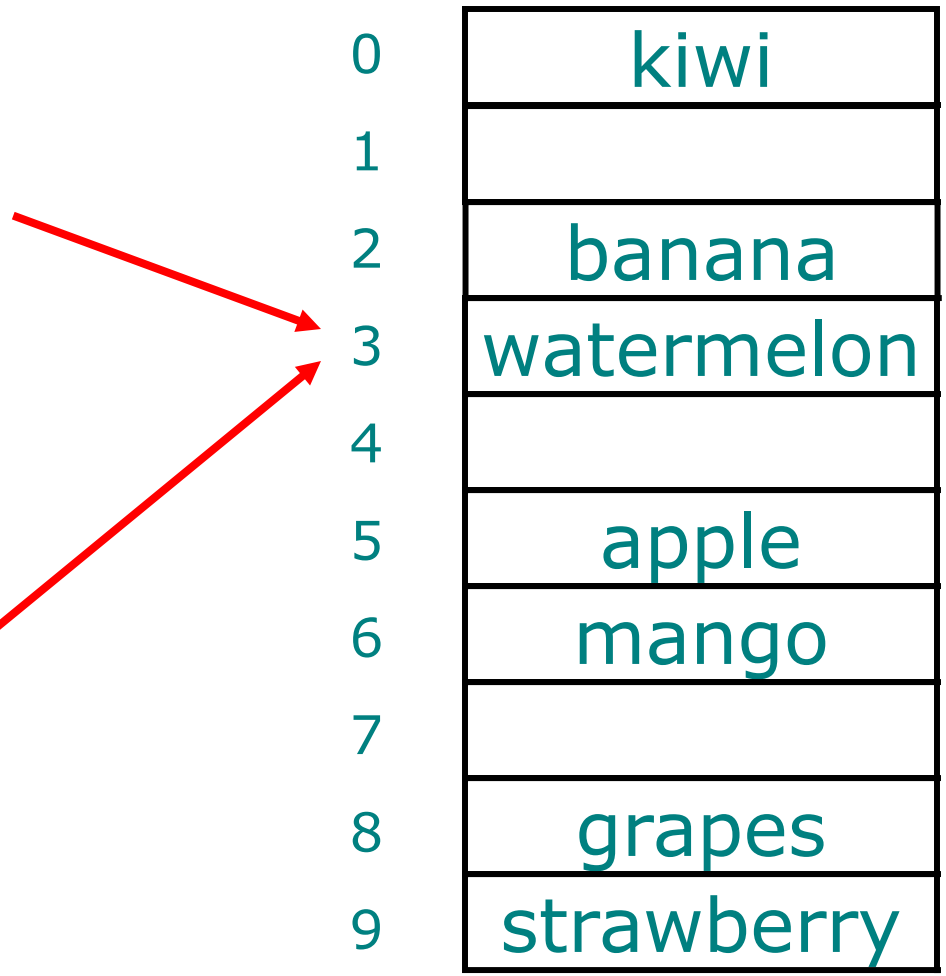
- **Perfect hash function**
  - **Unique values for each key**

Hash Function

- Suppose now

  hash("apple") = 5
  hash("watermelon") = 3
  hash("grapes") = 8
  hash("kiwi") = 0
  hash("strawberry") = 9
  hash("mango") = 6
  hash("banana") = 2
  hash("orange") = 3

- Collision
  - Same hash value for multiple keys



Scattering Hash Values

- Hash function should scatter hash values uniformly across range of possible values
  - Reduces likelihood of conflicts between keys
- Hash(<everything>) = 0
  - Satisfies definition of hash function
  - But not very useful (all keys at same location)
- Could use Math.abs(keyValue % N)
  - Might not distribute values well
  - Particularly if N is a power of 2

Scattering Hash Values

- Multiplicative congruency method
  - Produces good hash values
  - Hash value = Math.abs((a * keyValue) % N)
  - Where
    - N is table size
    - a is large prime number

Caution

- Use Math.abs(x % N) and not Math.abs(x) % N
- Why?
  - Math.abs(Integer.MIN_VALUE) == Integer.MIN_VALUE !
  - Will happen 1 in 2^{32} times (on average) for random int values

Hashing in Java

- Object class has built-in support for hashing
  - Method int hashCode( ) provides
    - Numerical hash value for any object
    - 32-bit signed int
- Default hashCode( ) implementation
  - Usually just address of object in memory
- Can override with new user definition
  - Must work with equals( )
  - Must satisfy the "hash code contract"

Java Hash Code Contract

- Java Hash Code Contract

1. If a.equals(b) == true, then we must guarantee

   a.hashCode( ) == b.hashCode( )

   - Converse is NOT required:

     a.hashCode( ) == b.hashCode( )

     does not imply a.equals(b) == true

2. hashCode() Must return same value for an object each time, provided information used in equals( ) comparisons on the object is not modified

When to Override hashCode

- You must write classes that satisfy the Java Hash Code Contract
- Otherwise there will be problems using classes that rely on hashing (e.g., HashMap, HashSet)
  - Possible problem – You add an element to a set but cannot find it during a lookup operation
- Does the default equals and hashCode satisfy the contract? Yes!
- If you over-ride equals you must ensure that the Contract is still satisfied, which usually means you must over-ride hashCode
- If you implement the Comparable interface you should provide the appropriate equals method which leads to the appropriate hashCode method

Java hashCode( )

- Implementing hashCode( )
  - Only include information used by equals( )
    - Else 2 "equal" objects → different hash values
  - Use as much of that information as you can
    - Help avoid same hash value for unequal objects
- Example hashCode( ) functions
  - For pair of Strings
    - 1st letter of 1st str
    - 1st letter of 1st str + 1st letter of 2nd str
    - Length of 1st str + length of 2nd str
    - ∑ letter(s) of 1st str + ∑ letter(s) of 2nd str

Art and Magic of hashCode( )

- There is no “right” hashCode function
  - Art involved in finding good hashCode function
  - Should “scatter” the values uniformly into the table
  - Should be FAST!