CMSC 132:
Object-Oriented Programming II

Hashing

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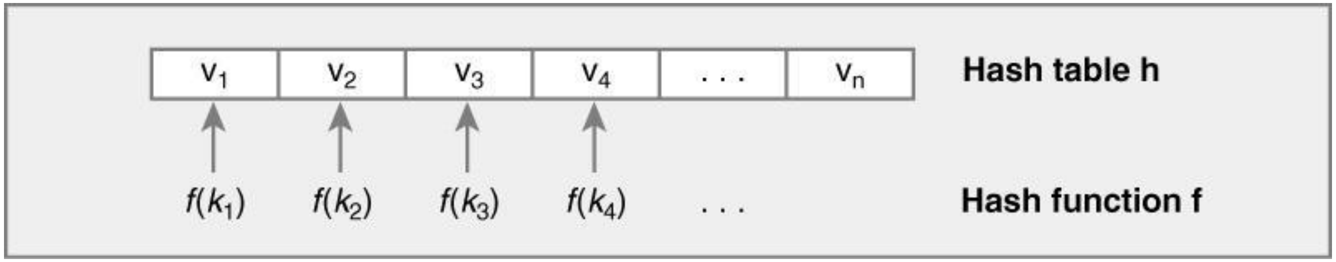
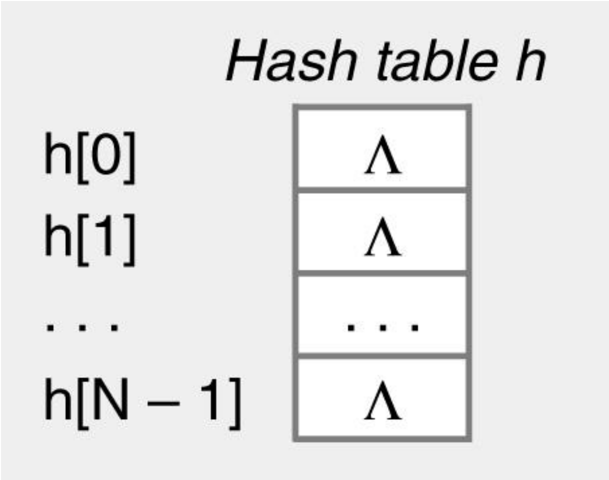
Hashing

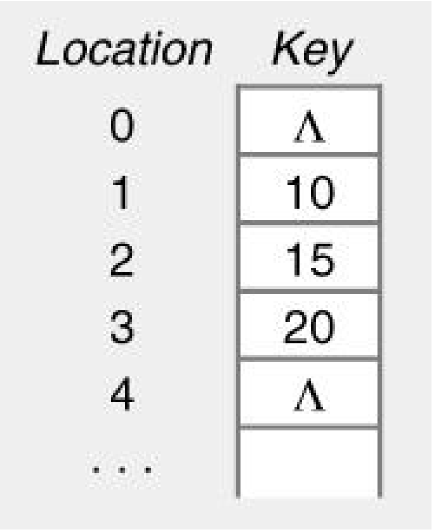
- **Hashing**
  - **Hashing function → function that maps data to a value (e.g., integer)**
  - **Hash Code/Hash Value → value returned by a hash function**
  - **Hash functions can be used to speed up data access**
  - **We can achieve O(1) data access using hashing**
- **Approach**
  - **Use hash function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





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**

0	kiwi
1	
2	banana
3	watermelon
4	
5	apple
6	mango
7	
8	grapes
9	strawberry

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**

0	kiwi
1	
2	banana
3	watermelon
4	
5	apple
6	mango
7	
8	grapes
9	strawberry

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 $\rightarrow$ 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
    - $\sum$ letter(s) of 1st str + $\sum$ 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!**