Hashing

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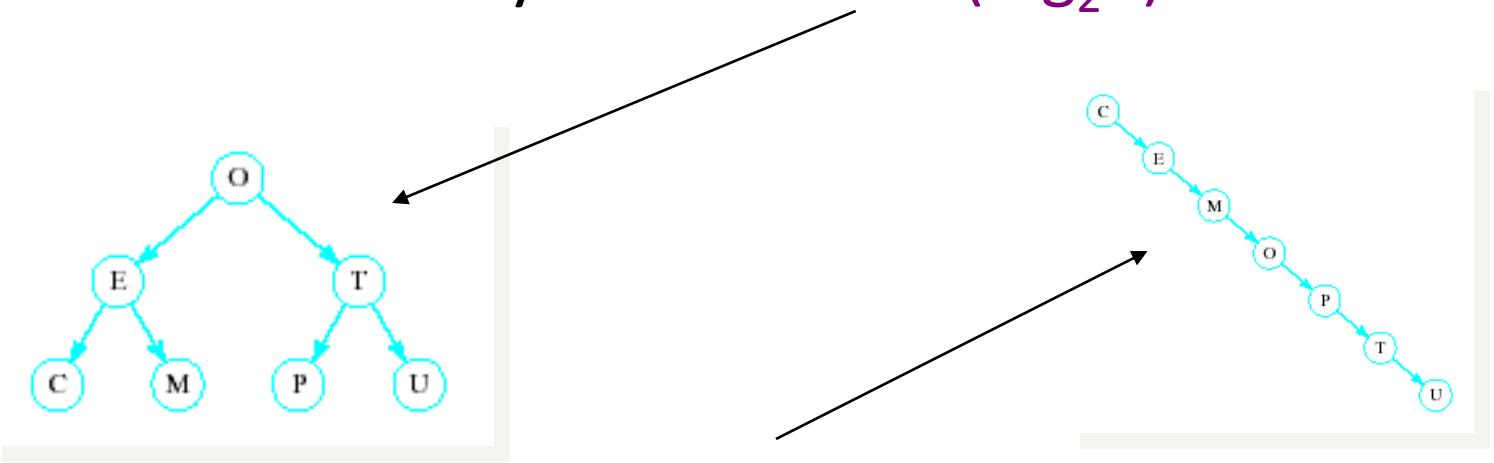
What do I have?

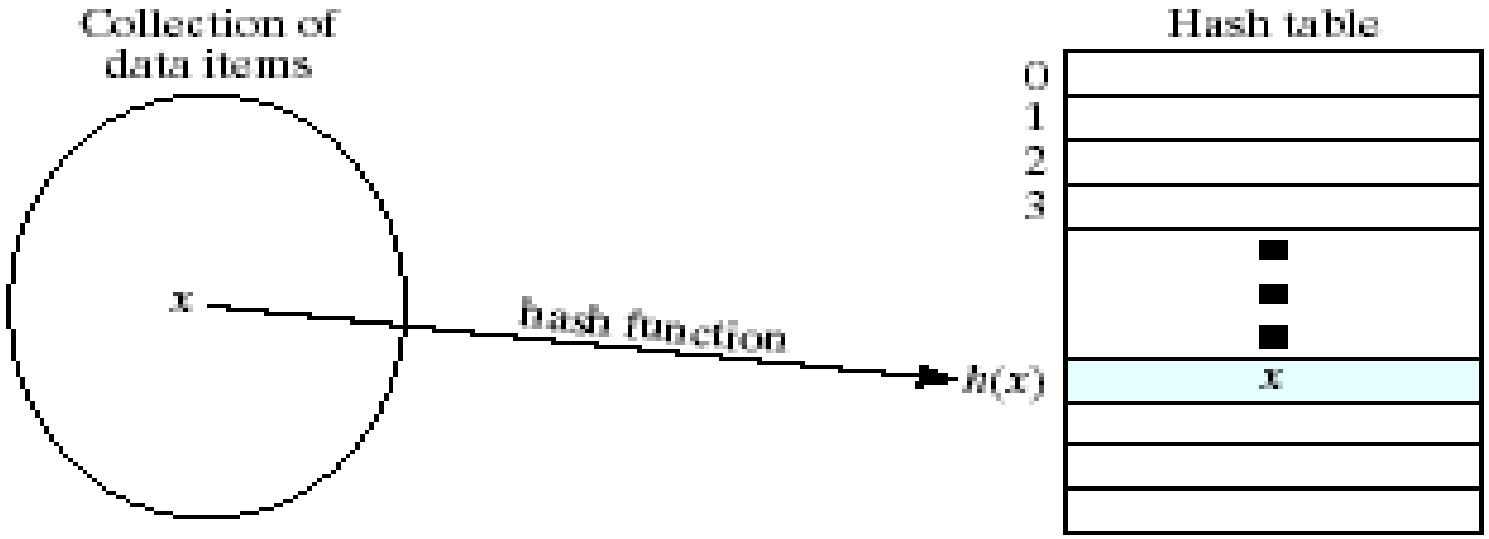
- Recall order of magnitude of searches
  - Linear search O(n)
  - Binary search $O(\log_2 n)$
  - Balanced binary tree search $O(\log_2 n)$



  - Unbalanced binary tree can degrade to O(n)

Hash Tables

- Sometime faster search is needed
  - Solution: use **hashing**
  - Value of key field fed into a hash function
  - Location in a hash table is calculated



Hashing

- Key to hashing
  - The hash function *h(x)*

Hash Functions

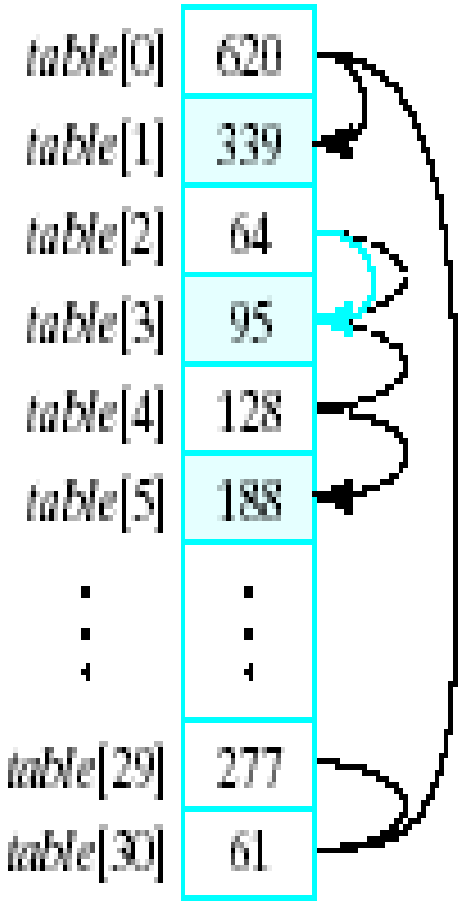
- Simple function could be to mod the value of the key by some arbitrary integer

```
int h(int i)
{  return   i % someInt;   }
```

- Note the max number of locations in the table will be same as **`someInt`**
- Note that we have traded space for performance
  - Table must be considerably larger than number of items anticipated

Collision Problem

- Collision: same value returned by `h(i)` for different values of `i`
  - `h(i)= i mod 31`



Hash Functions

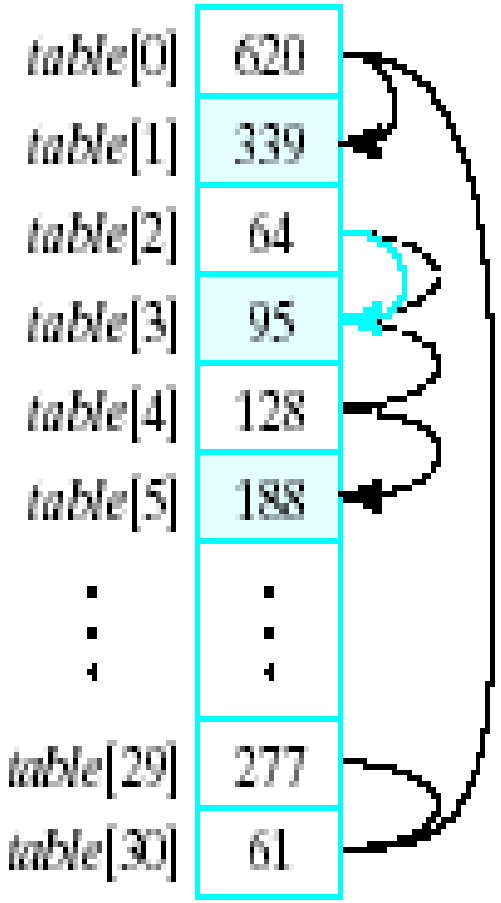
- Strategies for improved performance
  - Increase table capacity (less collisions)
  - Use a different collision resolution technique
  - Devise a different hash function

Hash Table Capacity

- Size of table must be 1.5 to 2 times the size of the number of items to be stored
- Otherwise probability of collisions is too high
- Sometimes may be hard to get the estimate of the number of items

Solution #1: Linear Probing

- Insertion
  - Linear search begins at collision location
  - Continues until empty slot found for insertion
- When retrieving a value linear probe until found
  - If empty slot encountered then value is not in table
- If deletions permitted
  - Slot can be marked so it will not be empty and cause an invalid linear probe



Example: Linear Probing

- h(x) = x % 31, the hash table has size of 31
  - Insertion order of 620, 64, 128, 467, 777, 35, 127, 282
- Use linear probing to solve collision

Solution #2: Quadratic Probing

- Linear probing can result in primary clustering
- Consider quadratic probing
  - Probe sequence from location *i* is
    i + 1, i – 1, i + 2^2, i – 2^2, i + 3^2, i – 3^2, …
  - Exercise: using quadratic probing to solve
  - Drawback: Secondary clusters can still form

Solution #3: Double Hashing

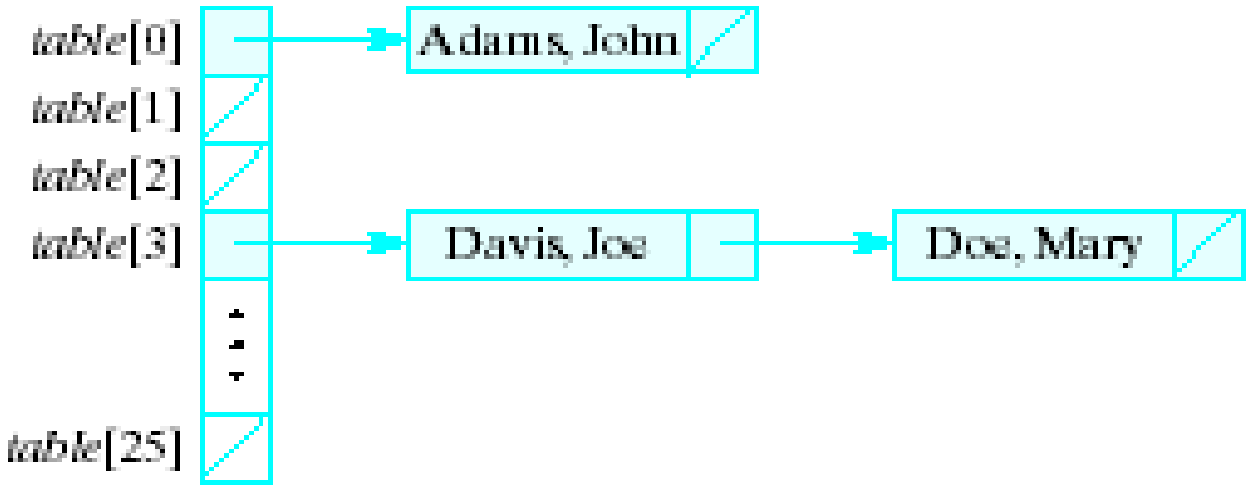
- Double hashing
  - Use a second hash function to determine probe sequence
  - Two hash functions
    - h1(x) = i
    - h2(x) = k
    - Probing sequence i, i+k, i+2k,….

Example: Double Hashing

- h(x) = x % 31, the hash table has size of 31
  - Insertion order of 620, 64, 128, 467, 777, 35, 127, 282
- Exercise: Use double hashing to solve collision
  - h1(x) = x % 31
  - h2(x) = 17 – (x % 17)

Solution 4: Chaining

- Chaining
  - Table is a list of head nodes to linked lists
  - When item hashes to location, it is added to that linked list



Improve the Hash Function

- Ideal hash function
  - Simple to evaluate
  - Scatters items uniformly throughout table (reducing collision)
- Modulo arithmetic not so good for strings
  - Possible to manipulate numeric (ASCII) value of first and last characters of a name

Do you know any good hash function?

- MD5 hashing, h(x)=16bytes
- SHA-1 hashing, h(x)=20bytes
- Hope you spend some time on googling these two to get a taste!!!!

Review

- Why Hashing?
- What does hashing do?
- One problem of hashing: collision
  - Degrade search performance
- 3 strategies to improve hashing performance
- Collision Strategies
- How to evaluate if a hash function is good?