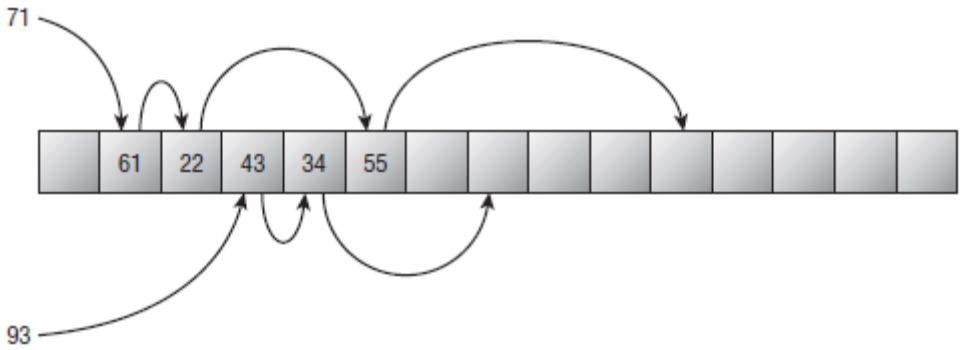
Hash Tables



Agenda

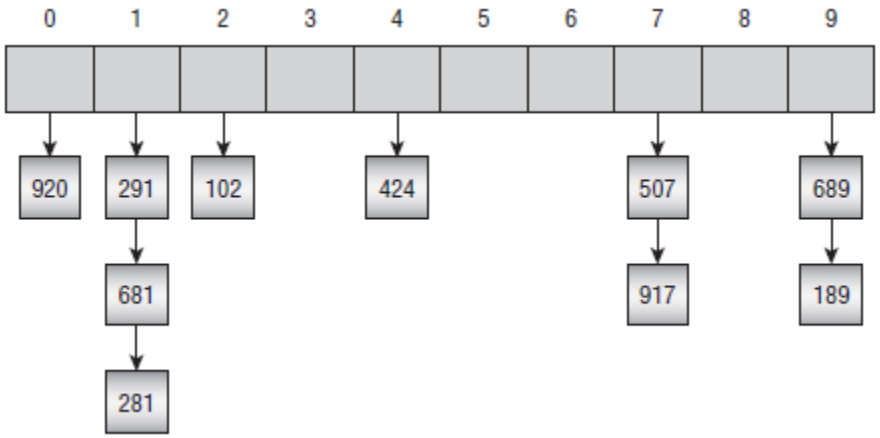
- Fundamentals
- Chaining
- Open Addressing
- Summary
- Exercises

Fundamentals

- Associative array, dictionary
- Hashing
- Collision resolution
- Fill percentage
- Resizing

Chaining

- Buckets with linked lists



Open Addressing

- Values are mapped into an array
- Probe sequence
- May not visit every position
- Fill percentage determines efficiency
- Removing items

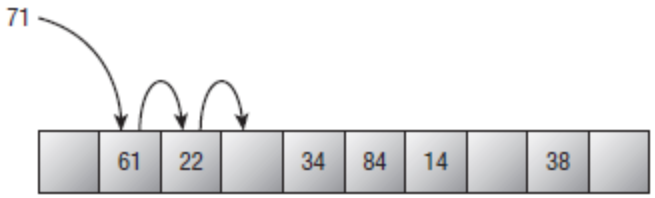
Deleting Items

- Mark items as deleted
- You may eventually want to rehash the table

Linear Probing

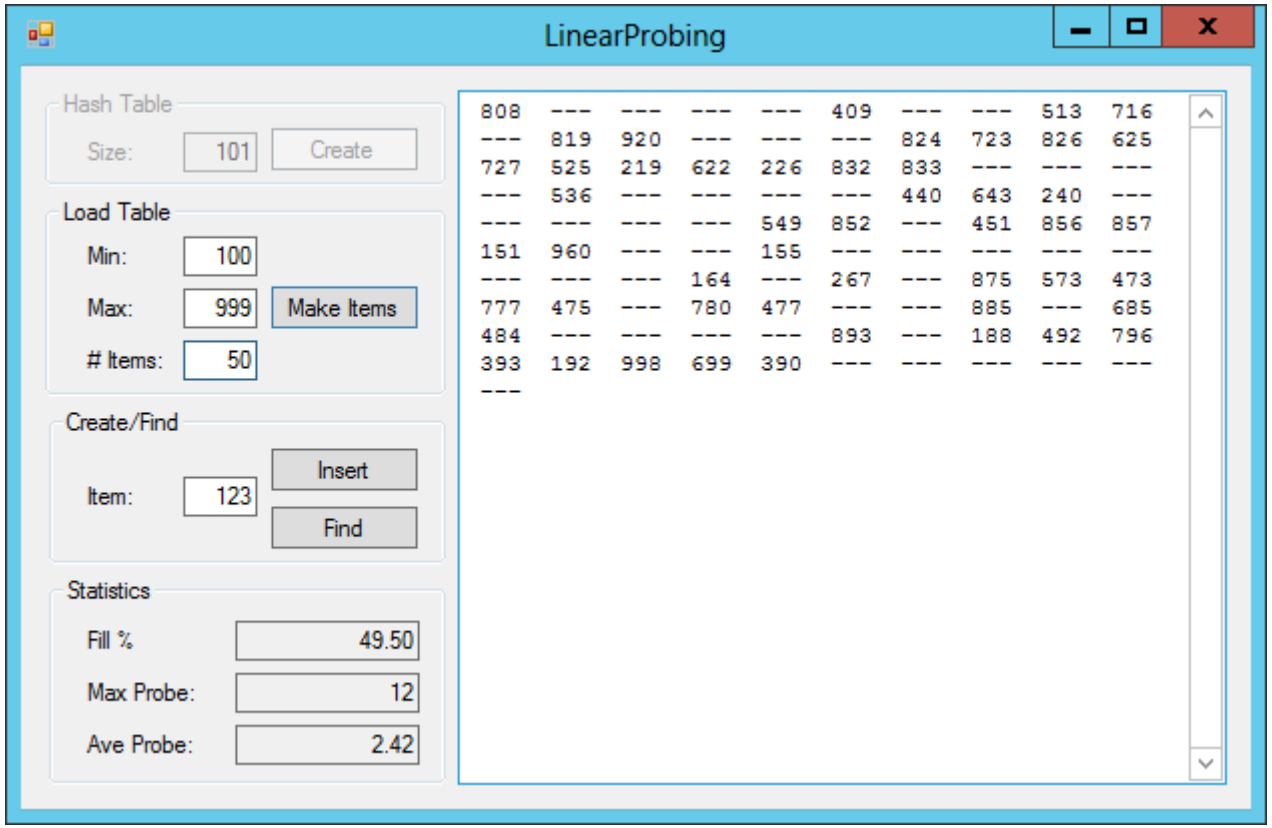
- Collision policy: add a stride value
- Example probe sequence:

  K, K + 1, K + 2, K + 3, ...



- Visits every position eventually
- Leads to primary clustering

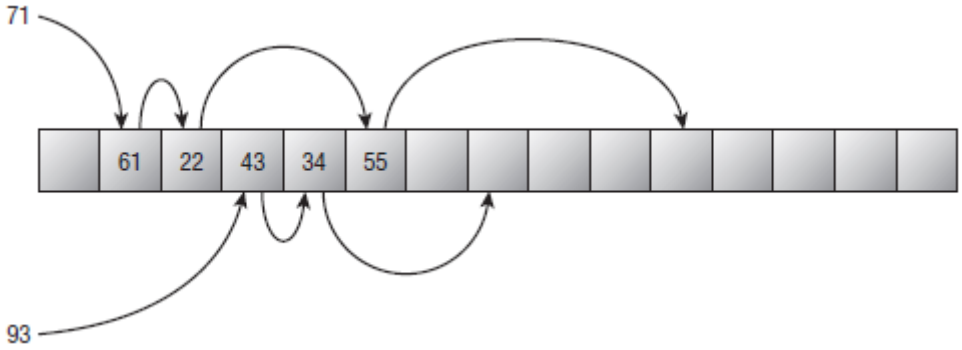
Primary Clustering



Quadratic Probing

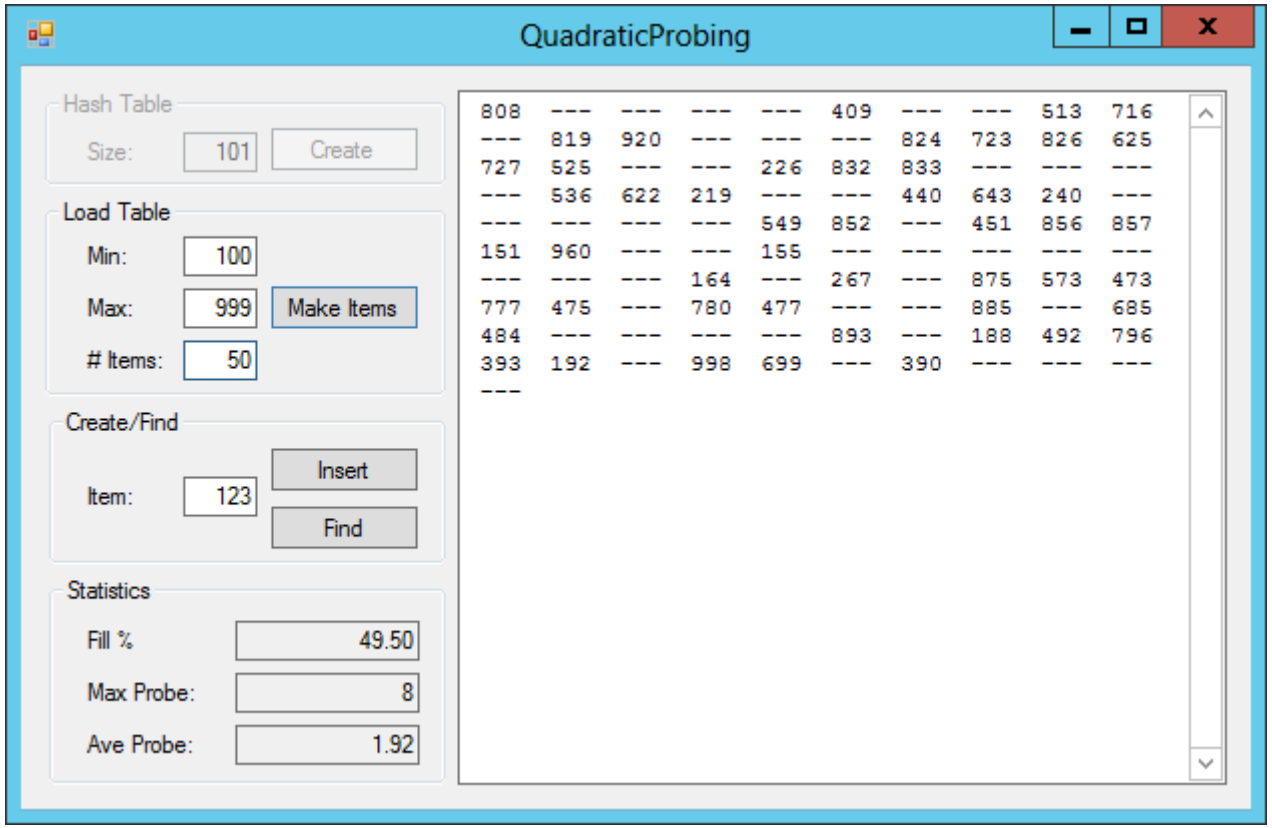
- Collision policy: add probe number squared
- Example probe sequence:

$$K, K + 1^2, K + 2^2, K + 3^2, \ldots$$



- May not visit every position
- Leads to secondary clustering

Secondary Clustering



Pseudorandom Probing

- V = value to hash
- K = $PR_1(V)$ initial address
- Collision policy: stride is $PR_2(K)$
- Example probe sequence:

  s = $PR_2(K)$

  K, K + s, K + 2 × s, K + 3 × s, ...
- May not visit every position
- Leads to secondary clustering

Here PR_1 and PR_2 are pseudo-random functions.

Double Hashing

- V = value to hash
- K = $PR_1(V)$ initial address
- Collision policy: stride is $PR_2(V)$
- Example probe sequence:

  s = $PR_2(V)$

  K, K + s, K + 2 × s, K + 3 × s, ...
- May not visit every position
- Eliminates secondary clustering

Here PR_1 and PR_2 are pseudo-random functions.

Ordered Hashing

- If you find an empty spot, drop the item there
- If you find a larger item, drop the new item there and rehash the larger one

Summary

- Fundamentals
- Chaining
- Open Addressing
  - Deleting Items
  - Linear Probing
    - Primary Clustering
  - Quadratic probing
    - Secondary Clustering
  - Pseudorandom Probing
  - Double Hashing
  - Ordered Hashing

Exercises

- Chapter 8 Exercises 1 – 17.
- Read *Essential Algorithms, 2e* Chapter 9 pages 227 – 252. (Stop before the section "Backtracking Algorithms.")