Efficiency of Hashing

Chapter 22

Data Structures and Abstractions with Java, 4e, Global Edition
Frank Carrano

Efficiency of Hashing

Observations about the time efficiency of these operations

- Successful retrieval/removal has same efficiency as successful search
- Unsuccessful retrieval/removal has same efficiency as unsuccessful search
- Successful addition has same efficiency as unsuccessful search
- Unsuccessful addition has same efficiency as successful search

Load Factor

- Definition of load factor:

$$\lambda = \frac{\textit{Number of entries in the dictionary}}{\textit{Number of locations in the hash table}}$$

  - Never negative
  - For open addressing, $1 \geq \lambda$
  - For separate chaining, λ has no maximum value
  - Restricting size of λ improves performance

Cost of Open Addressing

- Average number of searches for linear probing
  - For unsuccessful search

$$\frac{1}{2}\left\{1+\frac{1}{(1-\lambda)^2}\right\}$$

  - For successful search

$$\frac{1}{2}\left\{1+\frac{1}{(1-\lambda)}\right\}$$

Cost of Open Addressing

λ	Unsuccessful Search	Successful Search
0.1	1.1	1.1
0.3	1.5	1.2
0.5	2.5	1.5
0.7	6.1	2.2
0.9	50.5	5.5

FIGURE 22-1 The average number of comparisons required by a search of the hash table for given values of the load factor λ when using linear probing

Quadratic Probing and Double Hashing

- Average number of comparisons needed
  - For an unsuccessful search $\frac{1}{(1-\lambda)}$
  - For a successful search $\frac{1}{\lambda}\log\left(\frac{1}{1-\lambda}\right)$

Quadratic Probing and Double Hashing

λ	Unsuccessful Search	Successful Search
0.1	1.1	1.1
0.3	1.4	1.2
0.5	2.0	1.4
0.7	3.3	1.7
0.9	10.0	2.6

FIGURE 22-2 The average number of comparisons required by a search of the hash table for given values of the load factor λ when using either quadratic probing or double hashing

Cost of Separate Chaining

- Average number of comparisons during a search when separate chaining is used
  - For an unsuccessful search λ
  - For a successful search $1 + \lambda/2$
  - To maintain reasonable efficiency, you should keep $\lambda < 1$.

Cost of Separate Chaining

λ	Unsuccessful Search	Successful Search
0.1	0.1	1.1
0.3	0.3	1.2
0.5	0.5	1.3
0.7	0.7	1.4
0.9	0.9	1.5
1.1	1.1	1.6
1.3	1.3	1.7
1.5	1.5	1.8
1.7	1.7	1.9
1.9	1.9	2.0
2.0	2.0	2.0

FIGURE 22-3 The average number of comparisons required by a search of the hash table for given values of the load factor λ when using separate chaining

Maintaining the Performance of Hashing

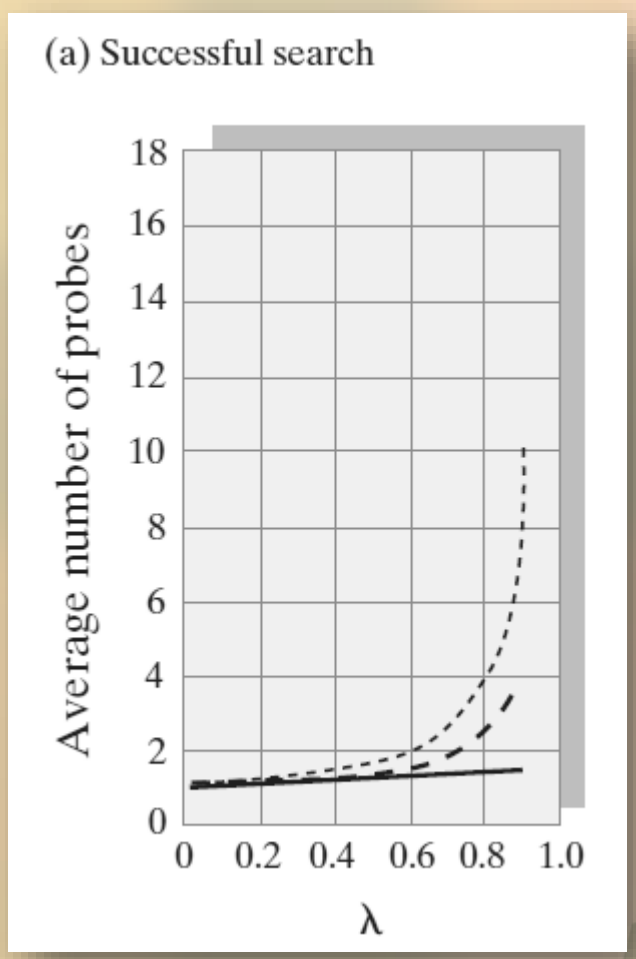
- To maintain efficiency, restrict the size of λ as follows:
  - $\lambda < 0.5$ for open addressing
  - $\lambda < 1.0$ for separate chaining
- Should the load factor exceed these bounds
  - Increase the size of the hash table

Rehashing

- When the load factor λ becomes too large must resize the hash table
- Compute the table's new size
  - Double its present size
  - Increase the result to the next prime number
  - Use method `add` to add the current entries in dictionary to new hash table

Comparing Schemes for Collision Resolution

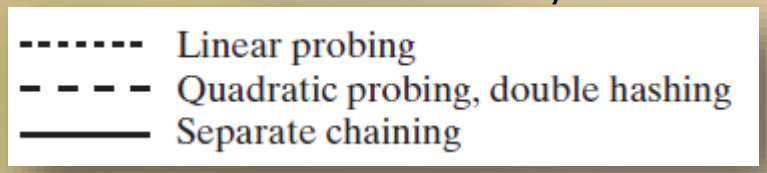
FIGURE 22-4 The average number of comparisons required by a search of the hash table versus the load factor λ for four collision resolution techniques when the search is (a) successful;

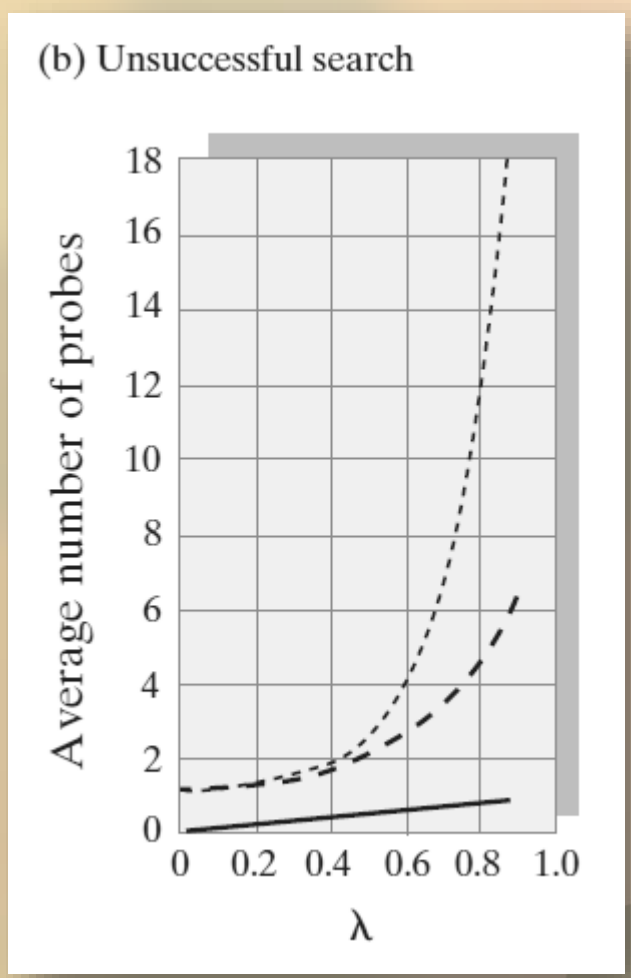


Linear probing
Quadratic probing, double hashing
Separate chaining

Comparing Schemes for Collision Resolution

FIGURE 22-4 The average number of comparisons required by a search of the hash table versus the load factor λ for four collision resolution techniques when the search is (b) unsuccessful;





End

Chapter 22