Hash Tables

Concepts

Goals

- Hash Functions
- Dealing with Collisions

Searching...Better than O(log *n*)?

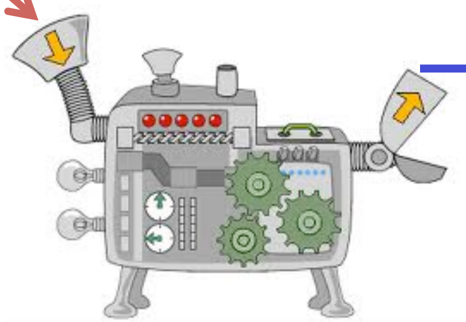
- Skip lists and AVL trees reduce the time to perform operations (add, contains, remove) from $O(n)$ to $O(\log n)$
- Can we do better? Can we find a structure that will provide $O(1)$ operations?
- Yes. No. Well, maybe. . .

Hash Tables

- Hash tables are similar to arrays except…
  - Elements can be indexed by values other than integers **Huh???**
  - Multiple values may share an index
    What???

Hashing with a Hash Function

Key
ie. string, url,etc.



Hash function

integer index

Hash Table

0	Key y
1	Key w
2	Key z
3	
4	Key x

Hash to index for storage AND retrieval!

Hashing to a Table Index

- Computing a hash table index is a two-step process:
  1. Transform the value (or key) to an integer (using the hash function)
  2. Map that integer to a valid hash table index (using the mod operator)
- Example App: spell checker
  - Compute an integer from the word
  - Map the integer to an index in a table (i.e., a vector, array, etc.)

Hash Function Goals

- FAST (constant time)
- Produce UNIFORMLY distributed indices
- REPEATABLE (ie. same key always results in same index)

Step 1: Transforming a key to an integer

- Mapping: Map (a part of) the key into an integer
  - Example: a letter to its position in the alphabet

- Folding: key partitioned into parts which are then combined using efficient operations (such as add, multiply, shift, XOR, etc.)
  - Example: summing the values of each character in a string

Key	Mapped chars (char in alpha)	Folded (+)	
eat	5 + 1 + 20	26	

Step 1: Transforming a key to an integer

- Shifting: can account for position of characters

Shifted by position in the word (right to left): 0th letter shifted left 0, first letter shifted left 1, etc.

each left shift =* 2

so for eat: t(20) shifts 0, a(2) shifts 1 and e(5) shifts 2—> 20+2+20

Key	Mapped chars (char in alpha)	Folded (+)	Shifted and Folded
eat	5 + 1 + 20	26	20 + 2 + 20 = 42
ate	1 + 20 + 5	26	4 + 40 + 5 = 49
tea	20 + 5 + 1	26	80 + 10 + 1 = 91

Step 1: Transform key to an integer

- Mapping: Map (a part of) the key into an integer
  - Example: a letter to its position in the alphabet
- Folding: key partitioned into parts which are then combined using efficient operations (such as add, multiply, shift, XOR, etc.)

  use positive arithmatic for positive integer values
  - Example: summing the values of each character in a string
- Shifting: get rid of high- or low-order bits that are not random
  - Example: if keys are always even, shift off the low order bit
- Casts: converting a numeric type into an integer
  - Example: casting a character to an int to get its ASCII value
  - ie.

```
char myChar = 'b';
int idx = (int) myChar;
```

Typical Hash Functions

- Character: the char value cast to an int → it's ASCII value
- Date: a value associated with the current time
- Double: a value generated by its bitwise representation
- Integer: the int value itself
- String: a folded sum of the character values
- URL: the hash on the host name
- Use the provided hash function!!! (ie. Java classes inherit a hashCode function …which you can override if desired

Step 2: Mapping to a Valid Index

- Use modulus operator (%) with table size:
  - Example: **idx = hash(val) % size;**
- Use only positive arithmetic or take absolute value
- To get a good distribution of indices, prime numbers make the best table sizes:
  - Example: if you have 1000 elements, a table size of 997 or 1009 is preferable

Hash Tables: Collisions

- A collision occurs when two values hash to the same index
- We'll discuss how to deal with ***collisions*** in the next lecture!
- Minimally Perfect Hash Function:
  - No collisions
  - Table size = # of elements
- Perfect Hash Function:
  - No collisions
  - Table size equal or slightly larger than the number of elements

Minimally Perfect Hash Funciton

Position of 3rd letter (starting at left, index 0) , mod 6

Alfred	`f = 5 % 6 = 5`
Alessia	`e = 4 % 6 = 4`
Amina	`i = 8 % 6 = 2`
Amy	`y = 24 % 6 = 0`
Andy	`d = 3 % 6 = 3`
Anne	`n = 13 % 6 = 1`

0	Amy
1	Anne
2	Amina
3	Andy
4	Alessia
5	Alfred

Hashing: Why do it??

- Assuming
  - Hash function can be computed in constant time
  - computed indices are equally distributed over the table

- Allows for $O(1)$ time bag/map operations!

Application Example

- spell checker
  - Know all your words before hand   aka the dictionary
  - Need FAST lookups so you can highlight on the fly
  - Compute an integer index from the string