CS61B Lecture #24: Hashing

Back to Simple Search

h is OK for small data sets, bad for large.

rch would be OK *if* we could rapidly narrow the search ns.

t in constant time could put any item in our data set into *bucket,* where # buckets stays within a constant factor

that buckets contain roughly equal numbers of keys.

would be constant time.

Hash functions

ust have way to convert key to bucket number: a *hash*

g/ 2a a mixture; a jumble. *b* a mess." *Concise Oxford y, eighth edition*

ata items.

Longs, evenly spread over the range $0..2^{63}-1$.

eep maximum search to $L = 2$ items.

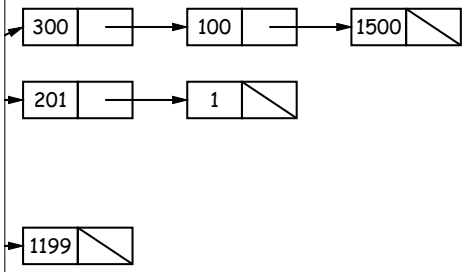
function $h(K) = K\%M$, where $M = N/L = 100$ is the buckets: $0 \le h(K) < M$.

2, 433, and 10002332482 go into different buckets, 0210, and 210 all go into the same bucket.

External chaining

buckets.

is a list of data items.



ts have same length, but average is $N/M = L$, the *load*

, hash function must avoid *collisions:* keys that "hash" es.

ching the Chains: Open Addressing

e data item in each bucket.

is a collision, and bucket is full, just use another.

to do this:

bes: If there is a collision at $h(K)$, try $h(K)+m$, $h(K)+$ wrap around at end).

probes: $h(K)+m$, $h(K)+m^2$, ...

shing: $h(K)+h'(K)$, $h(K)+2h'(K)$, etc.

$K) = K\%M$, with $M = 10$, linear probes with $m = 1$.

11, 3, 102, 9, 18, 108, 309 to empty table.

2	11	3	102	309		18	9

et slow, even when table is far from full.

ature on this technique, but

just settle for external chaining.

Filling the Table

y to be) constant-time lookup, need to keep #buckets nt factor of #items.

ble when load factor gets higher than some limit.

ust *re-hash* all table items.

eration constant time per item,

ng table size each time, get constant *amortized* time and lookup

hat is, that our hash function is good).

Functions: Other Data Structures I

List, LinkedList, etc.) are analagous to strings: e.g.,

```
= 1; Iterator i = list.iterator();
 hasNext()) {
 obj = i.next();
ode =
ashCode
bj==null ? 0 : obj.hashCode());
```

e spent computing hash function by not looking at entire mple: look only at first few items (if dealing with a List t).

collisions, but does *not* cause equal things to go to dif- ts.

Hash Functions: Strings

"$s_0 s_1 \cdots s_{n-1}$" want function that takes all characters sitions into account.

g with $s_0 + s_1 + \ldots + s_{n-1}$?

Java uses

$$h(s) = s_0 \cdot 31^{n-1} + s_1 \cdot 31^{n-2} + \ldots + s_{n-1}$$

odulo 2^{32} as in Java `int` arithmetic.

o a table index in $0..N-1$, compute `h(s)%N` (but *don't* e that is multiple of 31!)

to compute as you might think; don't even need multipli-

```
 = 0;
 i = 0; i < s.length (); i += 1)
r << 5) - r + s.charAt (i);
```


Identity Hash Functions

ess of object ("hash on identity") if distinct (!=) ob- ver considered equal.

Won't work for Strings, because `.equal` Strings could nt buckets:

```
= "Hello",
= H + ", world!",
= "Hello, world!";
```

als(S2), but `S1 != S2`.

Functions: Other Data Structures II

defined data structures ⇒ recursively defined hash

, on a binary tree, one can use something like

```
 == null)
eturn 0;
return someHashFunction (T.label ())
       ^ hash(T.left ()) ^ hash(T.right ());
```


ial Case: Monotonic Hash Functions

hash function is *monotonic:* either nonincreasing or ing.

y $k_1 > k_2$, then $h(k_1) \geq h(k_2)$.

time-stamped records; key is the time.

unction is to have one bucket for every hour.

, you *can* use a hash table to speed up range queries

applied to strings? When would it work well?

What Java Provides

ct, is function `hashCode()`.

eturns the identity hash function, or something similar. OK as a default?]

it for your particular type.

given on last slide, is overridden for type `String`, as well s in the Java library, like all kinds of `List`.

ashtable, `HashSet`, and `HashMap` use `hashCode` to give t-up of objects.

```
yType,ValueType> map =
ashMap<>(approximate size, load factor);
, value);          // Map KEY -> VALUE.
t(someKey)         // VALUE last mapped to by SOMEKEY.
ntainsKey(someKey) // Is SOMEKEY mapped?
ySet()             // All keys in MAP (a Set)
```

Characteristics

od hash function, add, lookup, deletion take $\Theta(1)$ time,

es where one looks up *equal* keys.

or range queries: "Give me every name between Martin [Why?]

robably not a good idea for small sets that you rapidly iscard [why?]

Perfect Hashing

of keys is *fixed*.

e hash function might then hash every key to a differ-*rfect hashing*.

, there is no search along a chain or in an open-address the element at the hash value is or is not equal to the

, might use first, middle, and last letters of a string -digit base-26 numeral). Would work if those letters all strings in the set.

e the Java method, but tweak the multipliers until all different results.

Comparing Search Structures

ms, k is #answers to query.

	Unordered List	Sorted Array	Bushy Search Tree	"Good" Hash Table	Heap
	$\Theta(N)$	$\Theta(\lg N)$	$\Theta(\lg N)$	$\Theta(1)$	$\Theta(N)$
ed)	$\Theta(1)$	$\Theta(N)$	$\Theta(\lg N)$	$\Theta(1)$	$\Theta(\lg N)$
	$\Theta(N)$	$\Theta(k+\lg N)$	$\Theta(k+\lg N)$	$\Theta(N)$	$\Theta(N)$
	$\Theta(N)$	$\Theta(1)$	$\Theta(\lg N)$	$\Theta(N)$	$\Theta(1)$
st	$\Theta(N)$	$\Theta(1)$	$\Theta(\lg N)$	$\Theta(N)$	$\Theta(\lg N)$