CSE 373: Hash Tables
(using them and dealing with collisions)

Chapter 5

Hash Table Sets: Use

Hash tables can be used to store sets

e.g., the set of all departments represented in CSE 373

```
typedef enum {ACMS, ARCH, ART, BIOCHM, …} dept;
```

Approach: Just store the departments themselves in the hash table:

- to add a new department, `Insert()` it
- to see if a department is represented, `Find()` it

Hash Table Sets: Implementation

Data Structure

```
typedef struct _HashTableStruct {
          int tablesize;
          dept *data;
        } HashTableStruct;
typedef HashTableStruct *HashTable;
```

Sample Operation

```
Insert(HashTable T,dept D)
```

- hash D to get an index, I
- check whether data[I] is empty (or already storing D)
- if so, set data[I] = D
- else deal with the conflict

Hashing Records

Goal: store the CSE 373 class list as a Hash Table

```
typedef struct _student {
          name first, last;
          int UWID;
          name email;
          char college;
          dept major;
          int class;
        } student;
```

Implementation:

Same as set, but array of students rather than departments

Hashing Records: Design Decisions

Design Decisions:

What to hash on?

- last name?
- first name?
- student ID?
- email?
- some combination thereof?

How to look someone up?

- supply entire record?
- supply just a single field?

Another Hash Table Interface

Some hash tables separate key from data:

```
void Insert(HashTable,KeyType,DataType);
DataType Find(HashTable,KeyType);
```

Question: How to implement a database?

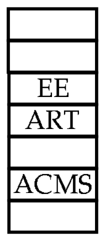
Goals:

- store records as in class list example
- be able to search based on *any* field (or some subset)
- minimize space requirements

Load Factor

Load Factor: Density of hash table, λ

λ = # of stored elements / table size



$\lambda = 3/7$

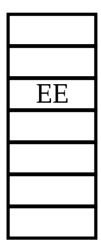
Ideally, we'd like $\lambda \approx 1.0$

Dealing with Collisions

What can we do when two keys hash to the same slot?

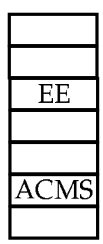
`Insert(T,EE)`

f(EE) = 2



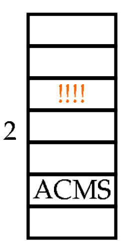
`Insert(T,ACMS)`

f(ACMS) = 5



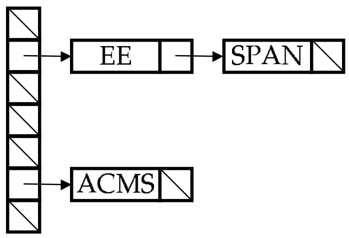
`Insert(T,SPAN)`

f(SPAN) = 2



Solution: Separate Chaining

Idea: At each position, store a list of the data that hashes to that position



Separate Chaining: Implementation

```
typedef struct _HashTable {
          int tablesize;
          List *datalist;
        } HashTable;
```

`Insert()`

- hash key
- see if key is already in list (`Find(datalist[I],…)`)
- if not, insert it into the list (`Insert(datalist[I],…)`)

(Note that we could replace lists with BSTs, hash tables)

Solution 2: Rehashing

Grow the size of the hash table as it gets full

But when?

- whenever there is a collision?
- whenever the λ reaches 1.0?
- whenever λ reaches k?
- whenever n% of the slots are in use?

Can we simply `realloc()` the data array?

Running Time of Rehashing

Assume that we'll rehash whenever λ = 1.0…

- starting with an array of size 11
- approximately doubling the size of the array (use the next prime larger than $2 \times$ tablesize)
- what is the total running time of inserting n keys?