DS 4300
Large Scale Information Storage and Retrieval

Foundations

Mark Fontenot, PhD
Northeastern University

Searching

- Searching is the most common operation performed by a database system
- In SQL, the SELECT statement is arguably the most versatile / complex.
- Baseline for efficiency is **Linear Search**
  - Start at the beginning of a list and proceed element by element until:
    - You find what you're looking for
   - You get to the last element and haven't found it

- **Record -** A collection of values for attributes of a single entity instance; a row of a table
- **Collection -** a set of records of the same entity type; a table
  - Trivially, stored in some sequential order like a list
- **Search Key** - A value for an attribute from the entity type
  - Could be >= 1 attribute

Lists of Records

- If each record takes up **x** bytes of memory, then for **n** records, we need **n*x** bytes of memory.
- Contiguously Allocated List
  - All **n*x** bytes are allocated as a single "chunk" of memory
- Linked List
  - Each record needs *x* bytes + additional space for 1 or 2 memory addresses
  - Individual records are linked together in a type of chain using memory addresses
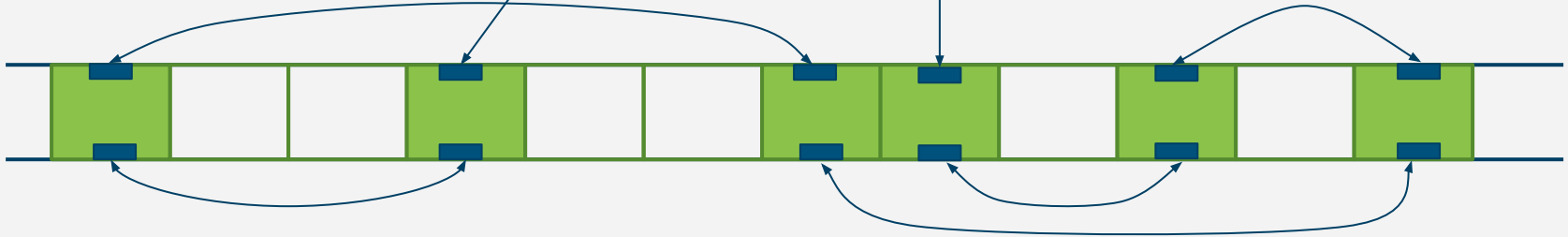
Contiguous vs Linked

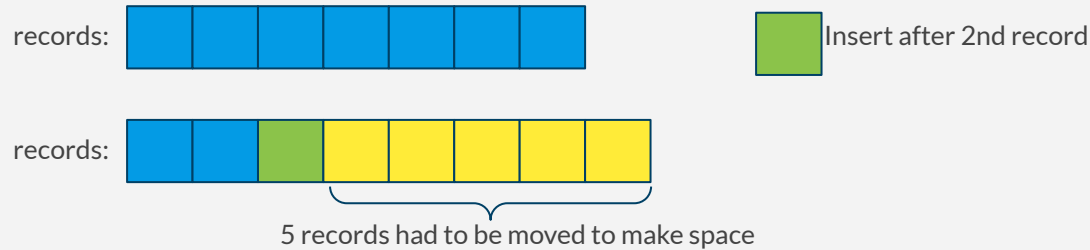6 Records Contiguously Allocated - **Array**
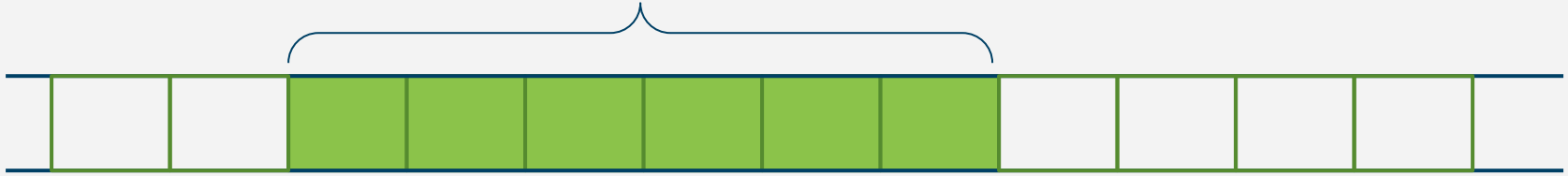
front
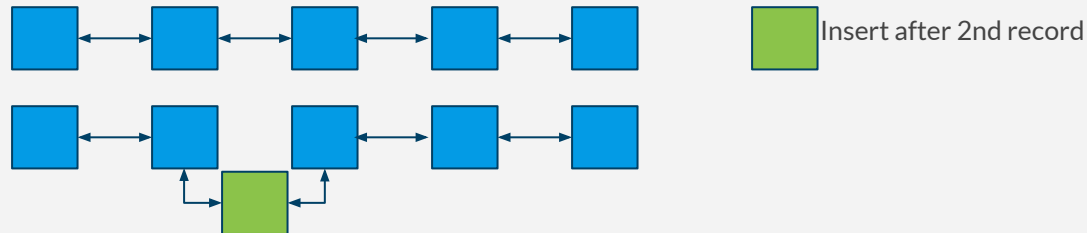
back

Extra storage for a
memory address

6 Records Linked by memory addresses - **Linked List**

- Arrays are faster for random access, but slow for inserting anywhere but the end

records:

records:

Insert after 2nd record

5 records had to be moved to make space

- Linked Lists are faster for inserting anywhere in the list, but slower for random access

Insert after 2nd record

Observations:

- Arrays
  - fast for random access
  - slow for random insertions
- Linked Lists
  - slow for random access
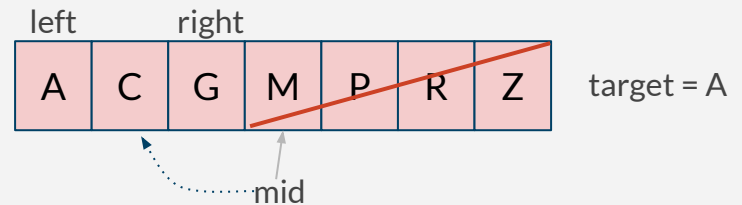 - fast for random insertions

Binary Search

- <u>Input</u>: array of values in sorted order, target value
- <u>Output</u>: the location (index) of where target is located or some value indicating target was not found

```
def binary_search(arr, target)
  left, right = 0, len(arr) - 1
  while left <= right:
    mid = (left + right) // 2
    if arr[mid] == target:
      return mid
    elif arr[mid] < target:
      left = mid + 1
    else:
      right = mid - 1
  return -1
```

left   right

| A | C | G | M | P | R | Z |

target = A

mid
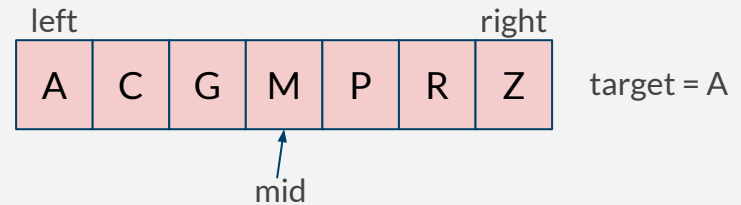
Since *target* < arr[mid], we reset *right* to *mid - 1*.

left   right

| A | C | G | M | P | R | Z |

target = A

mid

Time Complexity

- Linear Search
  - <u>Best case</u>: target is found at the first element; only 1 comparison
  - <u>Worst case</u>: target is not in the array; n comparisons
  - Therefore, in the worst case, linear search is $O(n)$ time complexity.
- Binary Search
  - <u>Best case</u>: target is found at *mid*; 1 comparison (inside the loop)
  - <u>Worst case</u>: target is not in the array; $log_2 n$ comparisons
  - Therefore, in the worst case, binary search is $O(log_2 n)$ time complexity.

Back to Database Searching

- Assume data is stored on disk by column id's value
- Searching for a specific id is fast.
- But what if we want to search for a specific *specialVal*?
  - Only option is linear scan of that column
- Can't store data on disk sorted by both id and specialVal (at the same time)
  - data would have to be duplicated → space inefficient

id	specialVal
1	55
2	87
3	50
4	108
5	122
6	149
7	145
8	120
9	50
10	83
11	128
12	117
13	119
14	119
15	51
16	85
17	51
18	145
19	73
20	73

Back to Database Searching

- Assume data is stored on disk by column id's value
- Se~~arching for a spec~~if~~ic id is fast~~
- Bu~~t~~
  - ~~sp~~
    - ~~column~~
- Ca~~n~~
  - an~~~~
  - data would have to be duplicated → space inefficient

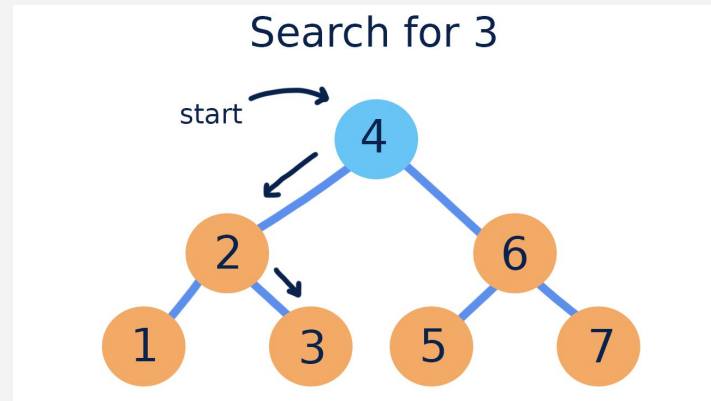> **We need an external data structure to support faster searching by *specialVal* than a linear scan.**

id	specialVal
1	55
2	87
3	50
4	108
5	122
6	149
7	145
8	120
9	50
10	83
11	128
12	117
13	119
14	119
15	51
16	85
17	51
18	145
19	73
20	73

What do we have in our arsenal?

1) An array of tuples (specialVal, rowNumber) sorted by specialVal
   a) We could use Binary Search to quickly locate a particular specialVal and find its corresponding row in the table
   b) But, every insert into the table would be like inserting into a sorted array - slow…
2) A linked list of tuples (specialVal, rowNumber) sorted by specialVal
   a) searching for a specialVal would be slow - linear scan required
   b) But inserting into the table would theoretically be quick to also add to the list.

Something with Fast Insert and Fast Search?

- Binary Search Tree - a binary tree where every node in the left subtree is less than its parent and every node in the right subtree is greater than its parent.

To the Board!