DS 4300

Large Scale Information Storage and Retrieval

Foundations

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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

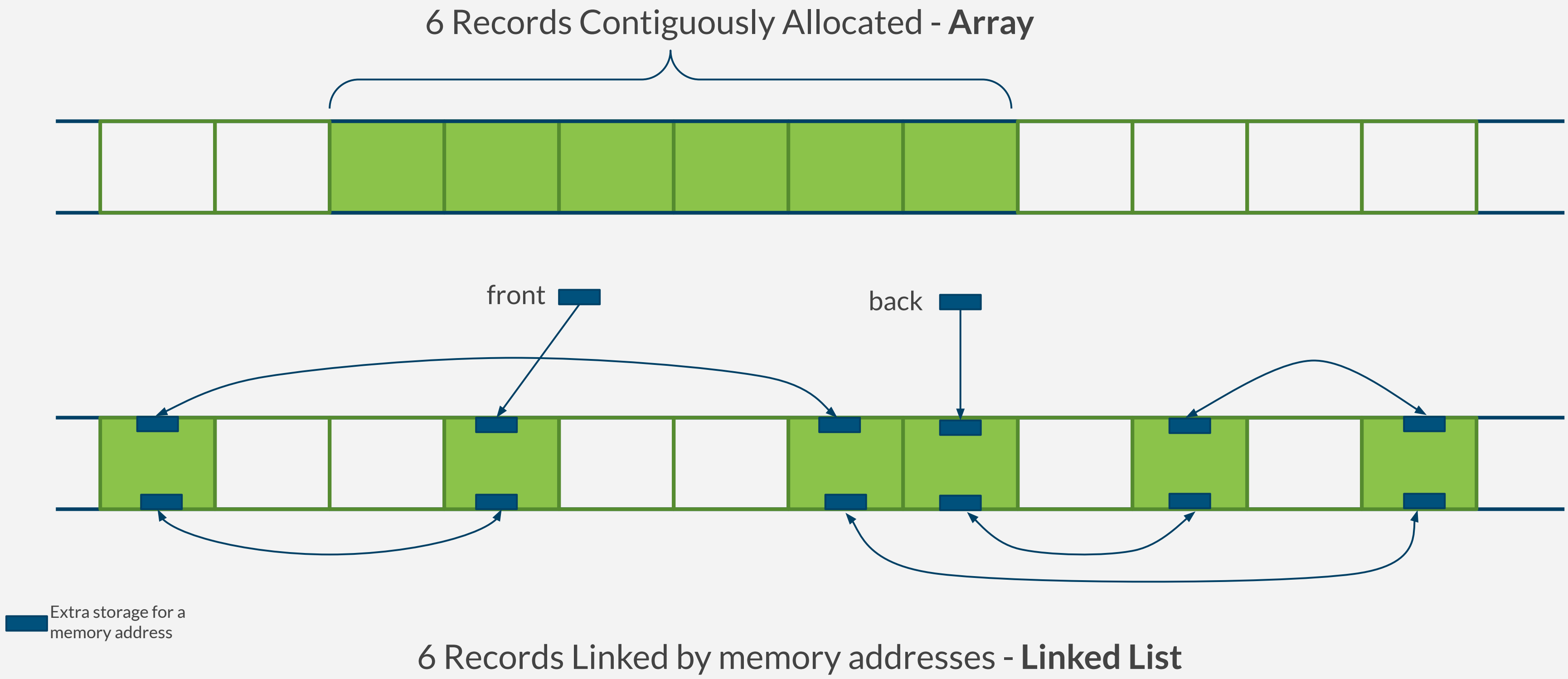
Searching

- **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

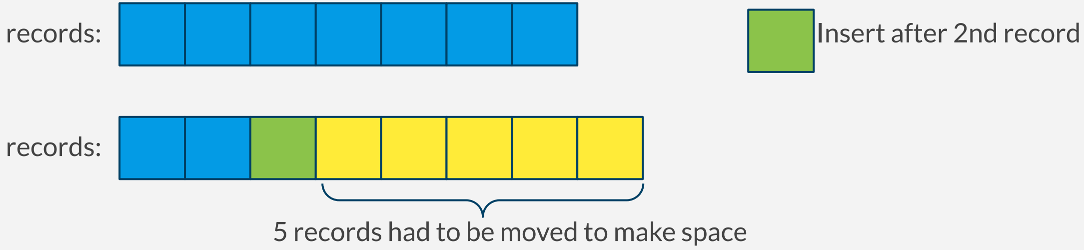
- If each record takes up ***x*** bytes of memory, then for ***n*** records, we need ***n**x*** bytes of memory.
- <u>Contiguously Allocated List</u>
  - All ***n**x*** bytes are allocated as a single "chunk" of memory
- <u>Linked List</u>
  - Each record needs *x* bytes + additional space for 1 or 2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

Contiguous vs Linked

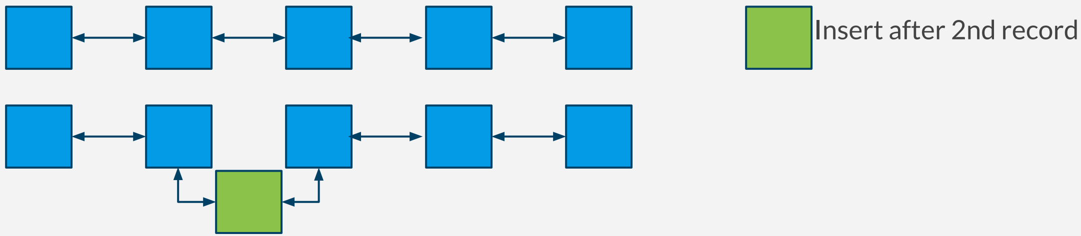


Pros and Cons

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



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



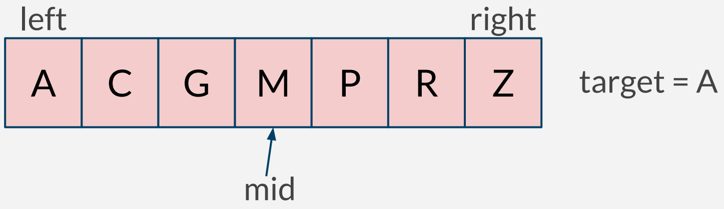
Observations:

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

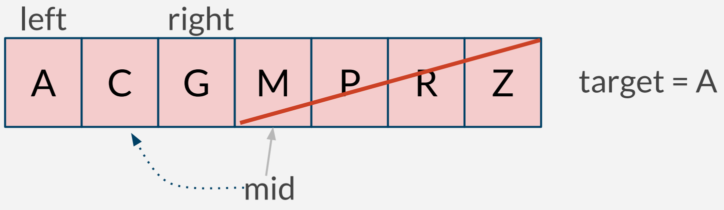
Binary Search

- Input: array of values in sorted order, target value
- Output: 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
```



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



Time Complexity

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

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  ○ data would have to be duplicated → space inefficient

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

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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.

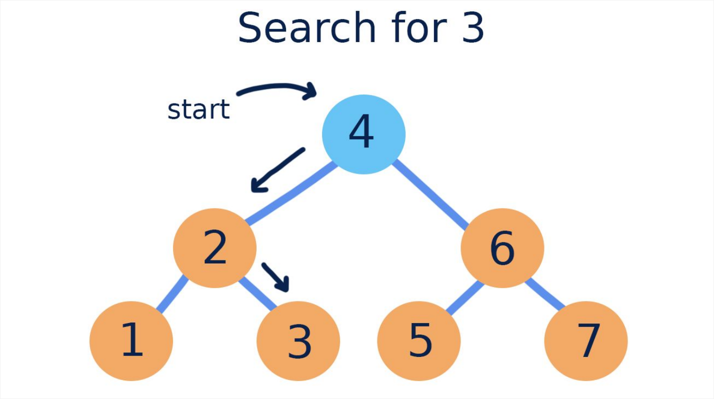

Image from: https://courses.grainger.illinois.edu/cs225/sp2019/notes/bst/

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