Data Structure Summary

A data structure is an implementation of an [abstract] interface.

- List
- Queue
- Stack
- Deque [double ended queue]
- Unordered Set [set]
- Sorted Set
- Map [set of key-value pairs]
- Sorted Map [sorted set of key-value pairs (kvp)]

Access and Modifification Characteristics

	get/set	**add/remove**
Arrays	*O(1)*	*O(1 + min(i,n-i))*
LinkedList	*O(1 + min(i,n-i))*	*O(1)**
Skiplist	*O(log n)*	*O(log n)*

`*given a pointer to the location, else traversal is necessary`

Set

Efficient for contains().

SortedSet

Efficient for find().

- Does a successor search [closest value ≥ to value]

Maps

Efficient for contains() [kvp]

SortedMap

Efficient for find() [kvp]

Array-based

Efficient for read / write. Expensive insertion / deletion.

ArrayList / ArrayStack

Efficient access anywhere. Efficient insertion / deletion at back [think stack].

- Implements **List** interface with an array
- superceded by ArrayDeque
- **get(), set() in O(1)**
- **add(), remove() in O(1 + n-i)**
- **resize is O(n)** [amortized]

```
// for m ≥ 1 add() / remove() calls, resize() will copy at most 2m
```

```
// the amortized cost of resize() for m calls is 2m/m = O(1)
```

ArrayQueue / ArrayDeque

Efficient access anywhere. Efficient insertion / deletion at front and back [think deque].

- Implements **List** interface with an array
- **get(), set() in O(1)**
- **add(), remove() in O(1 + min(i, n-i))**

- **resize is O(n)** [amortized]

```
// since ArrayQueue only supports addLast() and
removeFirst(), these are O(1)
```

DualArrayDeque

Efficient access anywhere. Efficient insertion / deletion at front and back [think deque].

- Implements **List** interface
- Uses two **ArrayStacks** front-to-front
- May be rebalanced if one array is much larger than the other
- **get(), set() in O(1)**
- **add(), remove() in O(1 + min(i, n-i))**

RootishArrayStack

List of Lists, of increasing size. Efficient space [sqrt(n) wasted space. Efficient access anywhere. Efficient insertion / deletion at back.

- Implements the **List** interface using multiple backing arrays
- Reduces 'wasted space' [unused space]
- At most: *sqrt(n)* unused array locations
- Good for space efficiency
- **get(), set() in O(1)**
- **add(), remove() in O(1 + n-i)**

```
// m ≥ 1 add() / remove() calls, results on O(m) time on
resize()
```

Linked Lists

Efficient insertion / deletion. Expensive access.

Singly Linked List [SLList]

Nodes with pointer to next node. Efficient insertion / deletion. Expensive access.

- Implements the Stack and Queue **interfaces**.
- **get(), set() in O(1 + i)**
- **add(), remove() in O(1)**

Doubly Linked List [DLList]

Nodes with pointers to previous and next nodes. Efficient insertion / deletion. Expensive access.

- Implements the Stack and Queue **interfaces**.
- **get(), set() in O(1 + min(i, n−i))**
- **add(), remove() in O(1 + min(i, n−i))**

SELList [Space-Efficient Linked List]

Nodes with pointers to previous and next nodes. Values stored as blocks in each node. [you can skip data] Efficient insertion / deletion. Expensive access.

- Implements the **List** interfaces
- wasted space: { n + O(b + n/b) }
- **get(), set() in O(1 + min(i, n−i)/*b*)**
- **add(), remove() in O(1 + min(i, n−i)/*b*)**

```
// m ≥ 1 add() / remove() calls, results in O(b•m) time on resize()
```

SkipLists

SLL with additional skipping pointers. Randomly generated structure. Allows for faster searches.

- Implements the **SortedSet** interface
- Successor search: **find(x) will return smallest value ≥ x**
- **get(), set() in O(log n)**
- **add(), remove() in O(log n)**

After Midterm

HashTable

- Unordered sets with fast access
- Associative array
  - Index elements into a range of int
  - for non-integer elements, use hashCode()

ChainedHashTable

- Implements the **USet** interface
- **find(), add(), remove() in O(n_i)**
  - where *n_i* is based of size of list at index

```
// m ≥ 1 add() / remove() calls, results in O(m) time on
resize()
```

Binary Tree

- Nodes with up to two child nodes

Binary Search Tree [BST]

- Implements the **SSet** interface
- **find(), add(), remove() in O(n)**

Random Binary Search Trees [RBST]

Balanced trees are statistically more likely

- Implements the **SSet** interface
- **contructed in O(n•log(n))**
- ** in O(n)**
- **find(), add(), remove() in O(log n)**

```
// search path is at most 2•log(n) + O(1)
```

Treaps

Has an extra priority:
Parent priority should be less than child priority.
This has the property of bounding the height of the tree.

- Implements the **SSet** interface
- Priorities are randomly applied
- **contructed in O(n•log(n))**
- **find(), add(), remove() in O(log n)**

Scapegoat Tree

BST that with height maintained within O(log n), rebuilt if too unbalanced

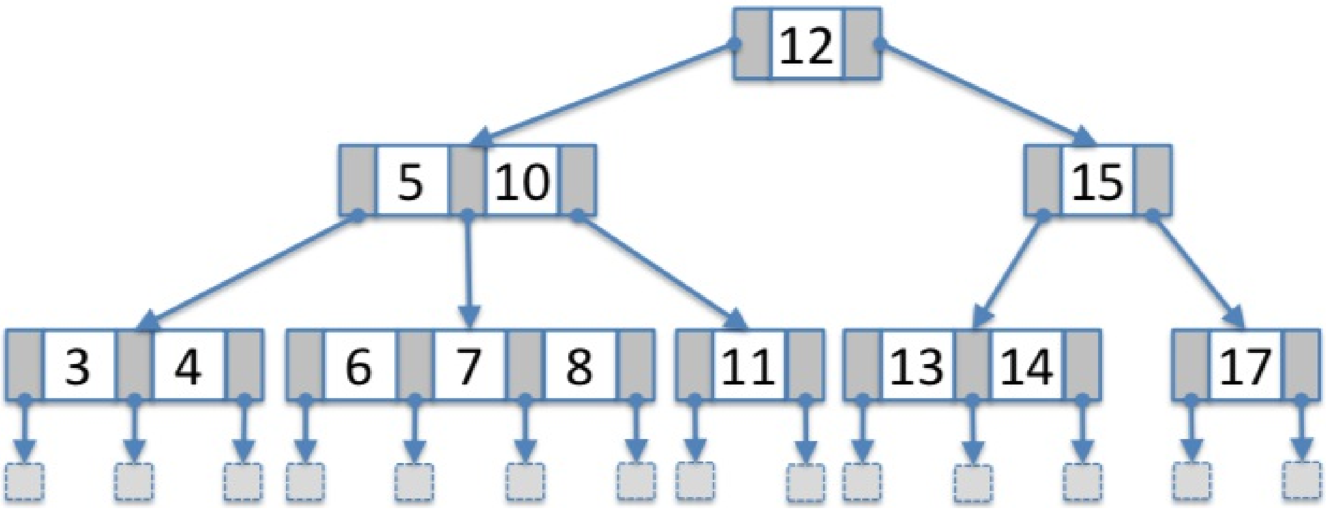
- Implements the **SSet** interface
- Rebuild only one search path that triggered rebuild
    - this ensures that not entire tree is rebuilt
- **rebuild() in O(log n) amortized**
- **find(), add(), remove() in O(log n)**

```
// m calls to add() / remove (), results in O( m•log(n) time
spent on rebuild()
```

2-4 Tree

Tree where every leaf has the same depth.

- Implements the **SSet** interface
- All leaves have equal depth
- All internal nodes have 2-4 children
- **find(), add(), remove() in O(log n) [worst-case]**



RedBlack Tree

A self-balancing binary search tree, built off a 2-4 Tree, where each node has a 'colour'.

- Implements the **SSet** interface
- Uses colour to remain balanced when adding / removing
  - There is the same number of black nodes on every root to leaf path
  - i.e. equal sum of colours on any root to leaf path
- No red nodes can be adjacent
  - red nodes must have black parent

- left-leaning: if left node is black, then right node must be black
- **Maximum height of 2•log(n)**
- **find(),add(), remove() in O(log n) [worst-case]**

Binary Search Tree Implementations

	find()	**add()**	**remove()**
BST	*O(n)*	*O(n)*	*O(n)*
RBST / Treaps	*O(log n)* [expected]	*O(log n)* [expected]	*O(log n)* [expected]
Scapegoat Trees	*O(log n)* [amortized]	*O(log n)* [amortized]	*O(log n)* [amortized]
2-4 / RedBlack Trees	*O(log n)* [worst-case]	*O(log n)* [worst-case]	*O(log n)* [worst-case]

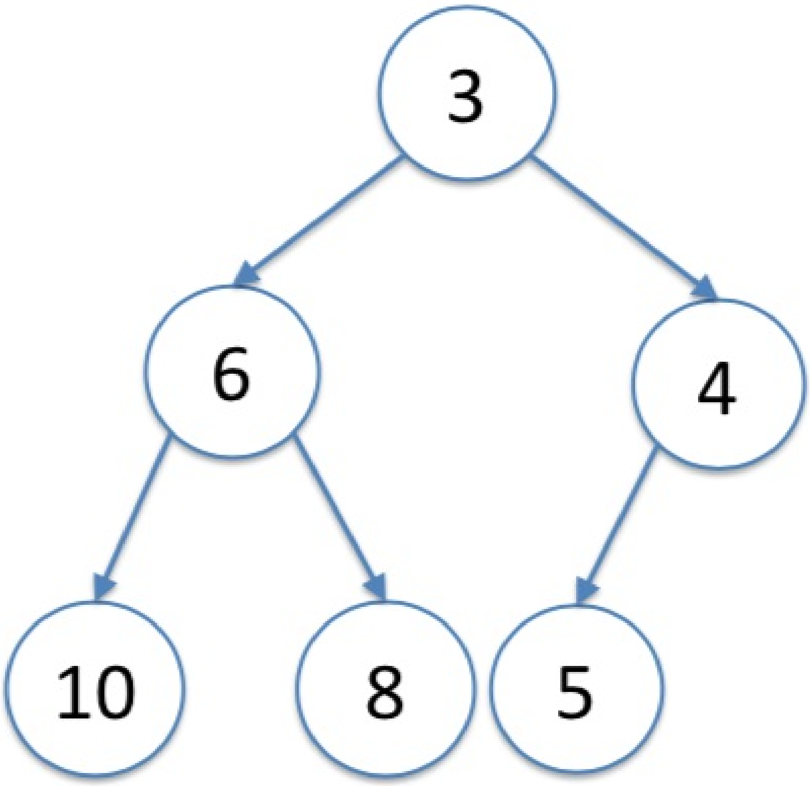
Sorted Set Implementations

	Runtime
Skiplists	*O(log n)* [expected]
Treaps	*O(log n)* [expected]
Scapegoat Trees	*O(log n)* [amortized]
2-4 / RedBlack Trees	*O(log n)* [worst-case]

Binary Heaps

A complete Binary Tree that also maintains the heap property.

- Implements the [priority] **Queue Interface**
- Allows to find / remove most extreme node with peek() / remove()
- **add(), remove() in O(log n)**
- **peek() in O(1)**




```
// m ≥ 1 add() / remove() calls, results in O(m) time on
resize()
```