122com Data structures and types

David Croft

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2017

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Overview

122com Data structs & types

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Arrays

Linked lists
   Array example
   LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

Quiz

Recap

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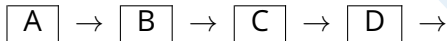A series of objects all of the same size and type.

```
array<char,5> arr = {'A', 'B', 'C', 'D', 'E'};
```

- Stored in contiguous blocks of memory.
- Python lists are functionally closest.
    - But are not arrays.
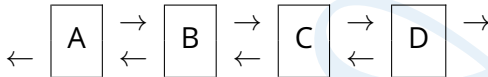- Can't be resized.

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The challenger for array's crown.

- Series of nodes, each of which points to the next element.
  - And to the previous element if it's a doubly linked list.

Singly linked

$\boxed{\text{A}} \rightarrow \boxed{\text{B}} \rightarrow \boxed{\text{C}} \rightarrow \boxed{\text{D}} \rightarrow$

Doubly linked

$\leftarrow \boxed{\text{A}} \overset{\rightarrow}{\underset{\leftarrow}{}} \boxed{\text{B}} \overset{\rightarrow}{\underset{\leftarrow}{}} \boxed{\text{C}} \overset{\rightarrow}{\underset{\leftarrow}{}} \boxed{\text{D}} \rightarrow$

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Linked lists II

A

Not in contiguous memory.

- Each node is separate.
- Scattered.
- C++ Dynamic memory (pointers!).
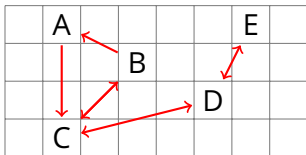 - Discussed in depth later in module.

- Why would we use linked lists instead of arrays?
  - Can change size.
  - Can quickly insert and delete elements.

```python
class Node:
    __prev = None
    __next = None
    value = None
```

```cpp
class Node
{
private:
    Node *prev;
    Node *next;

public:
    int value;
};
```

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Linked lists II

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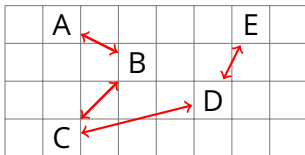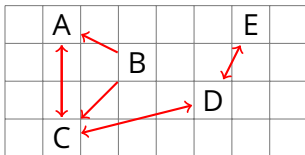

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Removing array elements

C

```
temp = ['A', 'B', 'C', 'D', 'E']
array<char,5> temp {'A', 'B', 'C', 'D', 'E'};
```

	A	B	C	D	E	

- Array in memory, multiple elements in a contiguous block.
- How do we remove elements from the middle?

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  1. Remove element from the array.

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Removing array elements
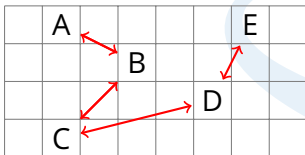
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- Array in memory, multiple elements in a contiguous block.
- How do we remove elements from the middle?
  1. Remove element from the array.
  2. Move next element to occupy the empty space.

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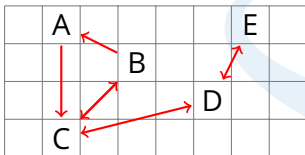|						
		A	C	D		E

- Array in memory, multiple elements in a contiguous block.
- How do we remove elements from the middle?
  1. Remove element from the array.
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  3. Repeat.

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Removing array elements

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```

	A	C	D	E			

- Array in memory, multiple elements in a contiguous block.
- How do we remove elements from the middle?
  1. Remove element from the array.
  2. Move next element to occupy the empty space.
  3. Repeat.
- Is very slow with large arrays.

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Removing linked list elements

- Linked list, separate elements scattered in memory.
- Each pointing to the next/prev element.
- How do we remove elements?

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Removing linked list elements

- Linked list, separate elements scattered in memory.
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    1. Change pointers.

Removing linked list elements
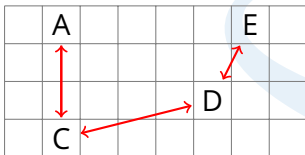
- ■ Linked list, separate elements scattered in memory.
- ■ Each pointing to the next/prev element.
- ■ How do we remove elements?
  - 1 Change pointers.

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Removing linked list elements

- Linked list, separate elements scattered in memory.
- Each pointing to the next/prev element.
- How do we remove elements?
  1. Change pointers.
  2. Delete old element.

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Recap

Advantages
- Inserting and deleting elements is very fast.
  - $O(1)$.
- No size limits, can keep adding new elements.
- Doesn't waste memory.

Disadvantages
- Not indexed.
  - Can't ask for the 20th element etc.
  - Have to step through the list (slow).
- Needs more memory than an array to store the same number of elements.
  - Have to keep track of where the next/prev nodes are.

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Data structures

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Arrays and linked lists are data structures.

- A specific way of storing data.
- Can see how the various elements of the structure are laid out in memory.
- Direct access to the underlying memory.

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Abstract data types

I

As we move to storing more complex information in our software we well start to encounter Abstract Data Types (ADTs).

- Software engineering principal.

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Abstract data types

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- Keep what a data type can do...

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Abstract data types

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  ...and how it does it separate.

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Abstract data types

As we move to storing more complex information in our software we well start to encounter ADTs.

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- Unlike data structure ADTs only concerned with the interface.

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Abstract data types

As we move to storing more complex information in our software we well start to encounter ADTs.

- Software engineering principal.
- Keep what a data type can do...
  ...and how it does it separate.

- Unlike data structure ADTs only concerned with the interface.
- Internals of ADTs can vary widely between implementations.

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Imagine an ADT like a car.

- It has a set of supported operations, go faster, go slower, turn left, turn right.

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ADT

Imagine an ADT like a car.

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ADT

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- Don't care if, internally, it's using a combustion engine or an electric motor.

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ADT

Imagine an ADT like a car.

- It has a set of supported operations, go faster, go slower, turn left, turn right.
- Don't care how it achieves these.
- Don't care if, internally, it's using a combustion engine or an electric motor.
- Only care about the result.
- Keep people away from the internal workings/data.

Programmer

Data

Interface
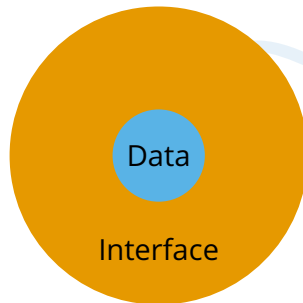
Queues

A First In First Out (FIFO) ADT.

- Ends of the queue called the front and back.
- New elements added to back of queue only.
  - Pushing - push(value)
- Old elements removed from front of queue only.
  - Popping - pop()
- No cutting in.

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Queues

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Queues   C

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Queues

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- Which would be better for a queue? An array or a linked list?
  - Linked list.

Array as a queue.
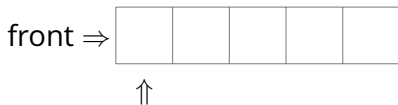
I

front ⇒

⇑

- Very similar to stacks.
  - Keep track of next free space.

  - Limited size.

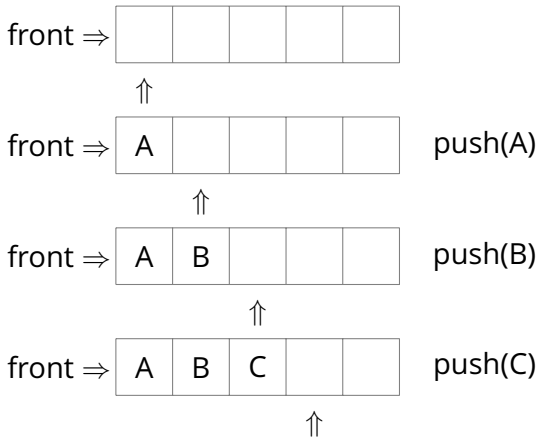# Array as a queue.

front ⇒

⇑
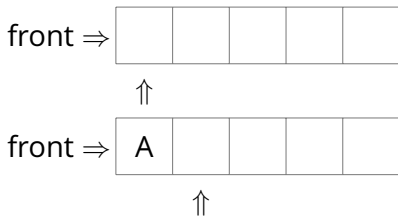
front ⇒ | A | | | | | push(A)

⇑

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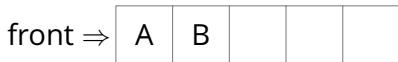
  - Limited size.

Array as a queue.

front ⇒

⇑

front ⇒ | A | | | | | push(A)

⇑

front ⇒ | A | B | | | | push(B)

⇑

- ■ Very similar to stacks.
  - ■ Keep track of next free space.

  - ■ Limited size.

Array as a queue.

- Very similar to stacks.
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Array as a queue. I

front ⇒ | | | | | |

⇑

front ⇒ | A | | | | | push(A)

⇑

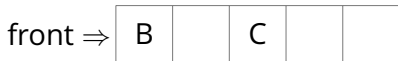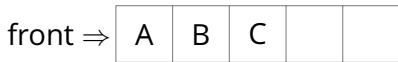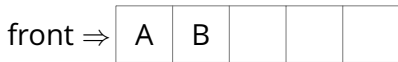front ⇒ | A | B | | | | push(B)

⇑
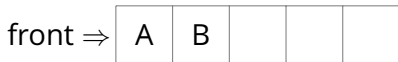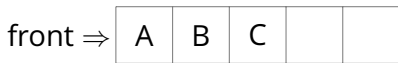
front ⇒ | A | B | C | | | push(C)

⇑

- Very similar to stacks.
  - Keep track of next free space.

  - Limited size.
- What happens when we pop()?
  - Have to shuffle every element forward one space.

  - Inefficient.

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Array as a queue.

front ⇒ [ ][ ][ ][ ][ ]

front ⇒ [A][ ][ ][ ][ ]   push(A)

front ⇒ [A][B][ ][ ][ ]   push(B)

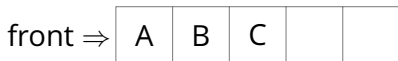front ⇒ [A][B][C][ ][ ]   push(C)

front ⇒ [ ][B][C][ ][ ]   pop()

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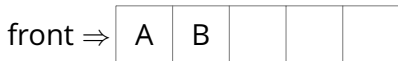

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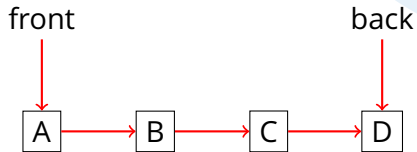

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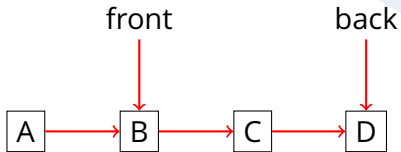
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Linked list as a queue.
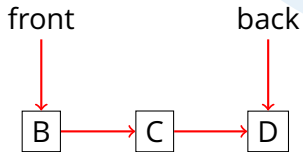
A

front

back

A → B → C → D

Linked list as a queue.

A

pop()

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Linked list as a queue.

A

pop()

pop() , pop()

front   back

B → C → D

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Linked list as a queue.

A

pop() , pop()

front   back

C → D
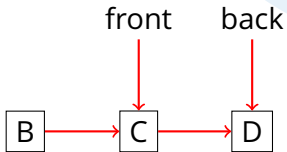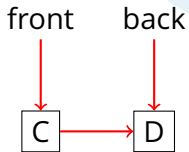
Linked list as a queue.

A

pop() , pop() , push(Z)

Linked list as a queue.

A

pop() , pop() , push(Z)

front   back

C → D → Z

Stacks C
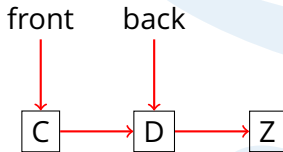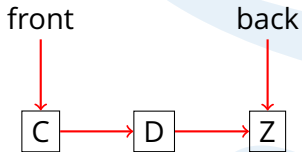
A First In Last Out (FILO) ADT.

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- No cutting in.

- Which would be better for a stack? An array or a linked list?
    - Doesn't matter performance wise.
    - Linked list if n is unknown.

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Array as a stack.

- Keep track of position of the next free space in the array.
- Arrays have a fixed size.
  - Can't hold more values than we have space for.

Array as a stack.

push(A)

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Array as a stack.

push(A)

push(B)

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Array as a stack.

push(A)

push(B)

push(C)

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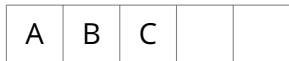Other
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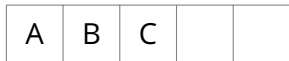Recap

Array as a stack.

push(A)

push(B)

push(C)

pop()

- Keep track of position of the next free space in the array.
- Arrays have a fixed size.
  - Can't hold more values than we have space for.

- An unordered ADT.
  - Items ordered by the set.

  - You have no control over it.
- Sets contain unique elements.
  - Can't contain duplicates.

- Can add items to a set.
- Can remove items from a set.
- Can see if an item is in a set.
- Can't get the nth element.
  - It's unordered remember.

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Sets   C

- An unordered ADT.
  - Items ordered by the set.
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- Can't get the nth element.
  - It's unordered remember.

A				

add(A)

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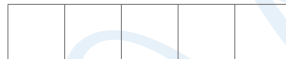 - It's unordered remember.

add(A)

add(B)

Sets C

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- Sets contain unique elements.
    - Can't contain duplicates.

- Can add items to a set.
- Can remove items from a set.
- Can see if an item is in a set.
- Can't get the nth element.
    - It's unordered remember.

A				

add(A)

A	B			

add(B)

A	B			

add(A)

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Sets **C**

- An unordered ADT.
  - Items ordered by the set.
  - You have no control over it.
- Sets contain unique elements.
  - Can't contain duplicates.

- Can add items to a set.
- Can remove items from a set.
- Can see if an item is in a set.
- Can't get the nth element.
  - It's unordered remember.

A				

add(A)

A	B			

add(B)

A	B			

add(A)

	B			

remove(A)

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122com Data structs & types

David Croft

Arrays

Linked lists
  Array example
  LL example

Data structures

Abstract data types

Queues

Stacks

Sets

Other

Trees

Quiz

Recap

...and the others

C

- Lots of other ADTs.
- Different names in different languages.

- Lists.
- Circular lists.
- Associative arrays.
  - Dictionaries/Maps.
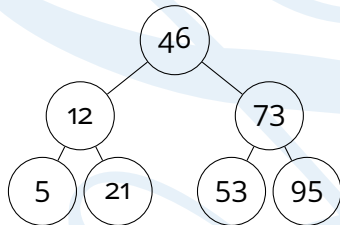- Double-ended queues.
- Trees.
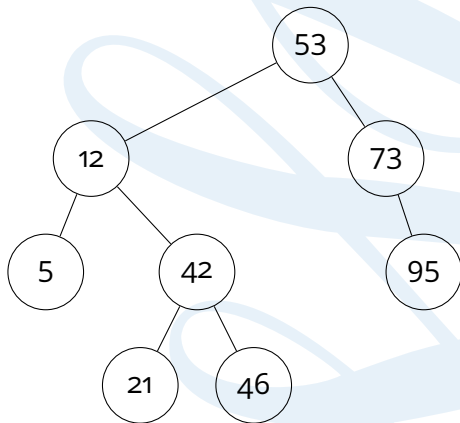- Graphs.

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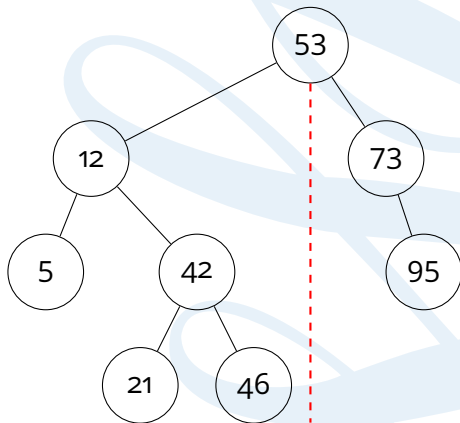# Break

Variation on linked lists.

- Made of nodes and relationships.
- Root node at top.
- Each node can have $\geq$ 0 children.

- Binary search tree.
  - Very common type.
  - Ordered.
  - Max two children.
  - Binary searching.
  - Very good for sets.

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Balance

A

- Trees can be balanced or unbalanced.
- Not required for all trees.
- Going to be talking about BSTs from here on.

- Unbalanced because more than a one node difference between the two halves.

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Balance

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- Trees can be balanced or unbalanced.
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  - For the whole tree…

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Balance

- Trees can be balanced or unbalanced.
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- Unbalanced because more than a one node difference between the two halves.
  - For the whole tree...
  - ...and one of the subtrees.

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122com Data structs & types

David Croft

Arrays
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Data structures
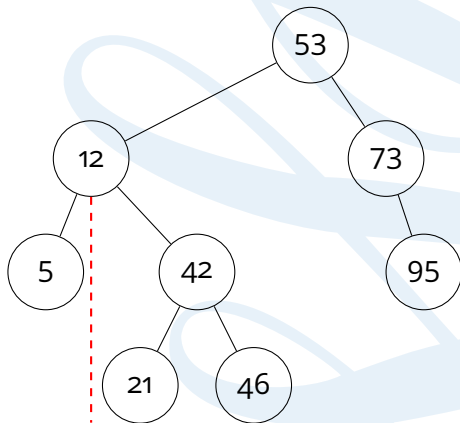Abstract data types
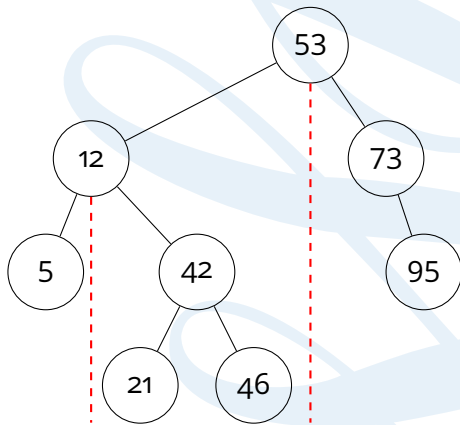Queues
Stacks
Sets
Other
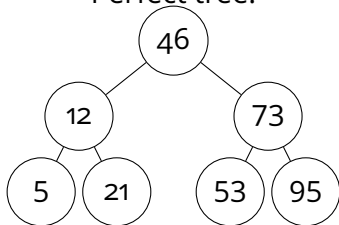**Trees**
Quiz
Recap

Balance

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Trees

Quiz

Recap

Balance

A

Important that you keep your BSTs balanced.

Degenerate tree.

Perfect tree.

Quiz

Stacks and queues are examples of _____

- Data structures.
- Linked lists.
- Arrays.
- Abstract Data Types.

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Stacks and queues are examples of _____

- Data structures.
- Linked lists.
- Arrays.
- Abstract Data Types.

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One advantage of linked lists over arrays is that _____

- They use less memory.
- They don't waste memory.
- They can be used for queues.
- They are faster to search though.

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One advantage of linked lists over arrays is that _____

- ■ They use less memory.
- ■ They don't waste memory.
- ■ They can be used for queues.
- ■ They are faster to search though.

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Stacks are a ____ type.

- FIFO.
- FOFI.
- FILO.
- FIDO.

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Stacks are a _____ type.

- FIFO.
- FOFI.
- FILO.
- FIDO.

The elements of a set can't _____

- Contain duplicates.
- Be sequences, ie. lists, strings.
- Be out of order.
- Be removed.

The elements of a set can't _____

- Contain duplicates.
- Be sequences, ie. lists, strings.
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ADTs separate the _____ of the type.

- Input and output.
- Attributes and methods.
- Implementation and interface.
- Code and software.

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ADTs separate the _____ of the type.

- ■ Input and output.
- ■ Attributes and methods.
- ■ Implementation and interface.
- ■ Code and software.

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Why do I care?

Everyone

- Need to understand the structures before we can pick the right one.
- Different data structures have very different characteristics.
- Huge effect on efficiency of your code.
- If you pick the right ADT it can save you a lot of code.
    - E.g. why write code to check for duplicates? Use a set and they can't exist.
    - E.g. why write code to find the most recent addition to a list, use a stack.

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Quiz
Recap

Recap

- Arrays.
  - Advantages/disadvantages.
- Linked lists .
  - Advantages/disadvantages.
  - How to insert/delete.
- Difference between data structure and ADTs.
- Stack.
  - FILO.
  - Using an array as one.
  - Using a LL as one.

- Queue.
  - FIFO.
  - Using an array as one.
  - Using a LL as one.

- Sets.
  - No duplicates.
  - Unordered.
- Trees.
  - Balanced/unbalanced.

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The End

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