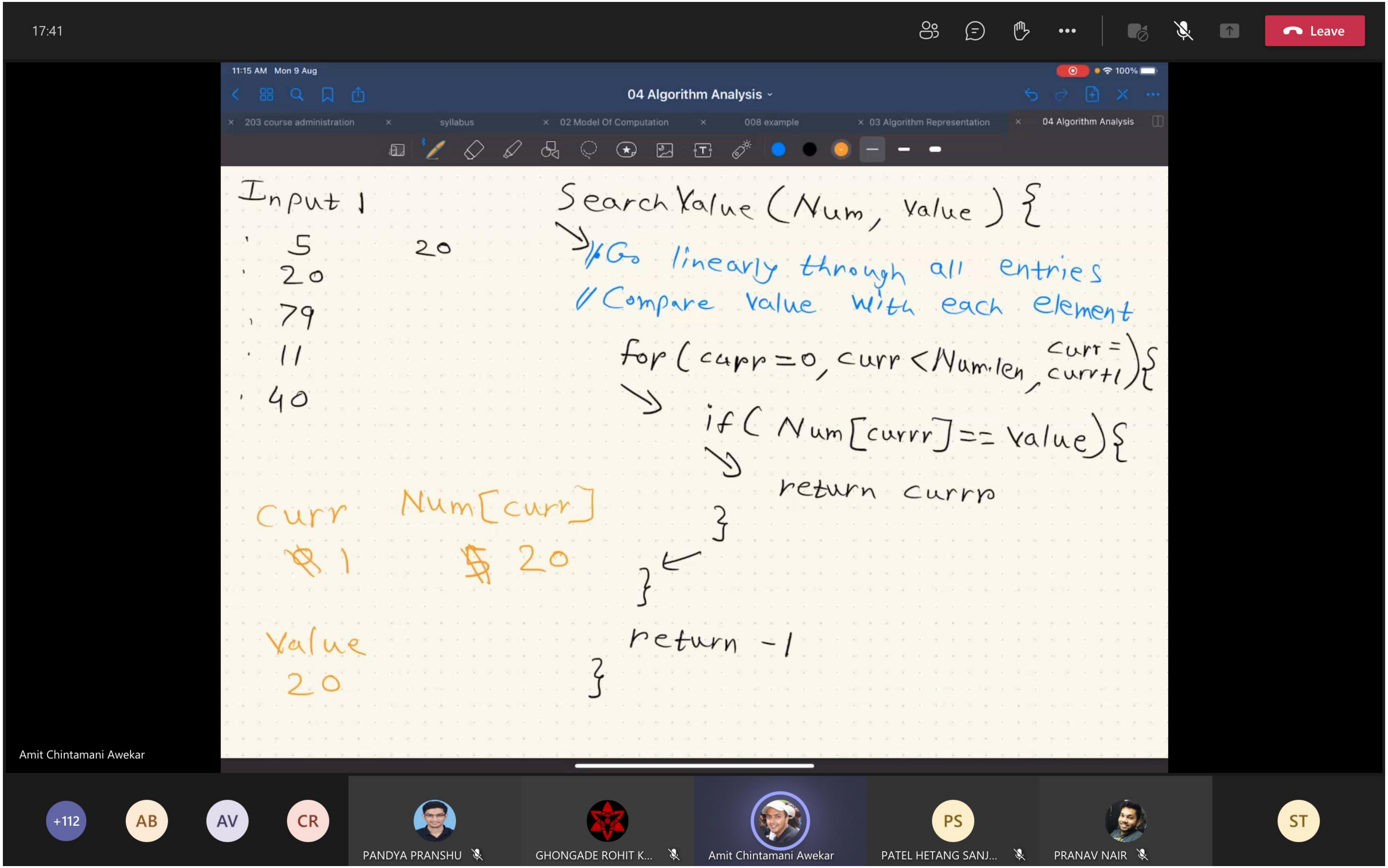
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04 Algorithm Analysis
203 course administration
syllabus
02 Model Of Computation
008 example
03 Algorithm Representation
04 Algorithm Analysis
Input
5
20
79
11
40
20
SearchValue (Num, Value) {
// Go linearly through all entries
// Compare value with each element
for (curr = 0, curr < Num.len, curr = curr+1) {
if (Num[curr] == value) {
return curr
}
}
return -1
}
curr
~~0~~ 1
Num[curr]
~~5~~ 20
Value
20
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AB
AV
CR
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04 Algorithm Analysis

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How to covert relation to function

- Consider only the worst case
- Average case
- Best case

Value absent

Value present at the end

Flight

Industrial plant

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$f(n) \in \Theta(g(n))$

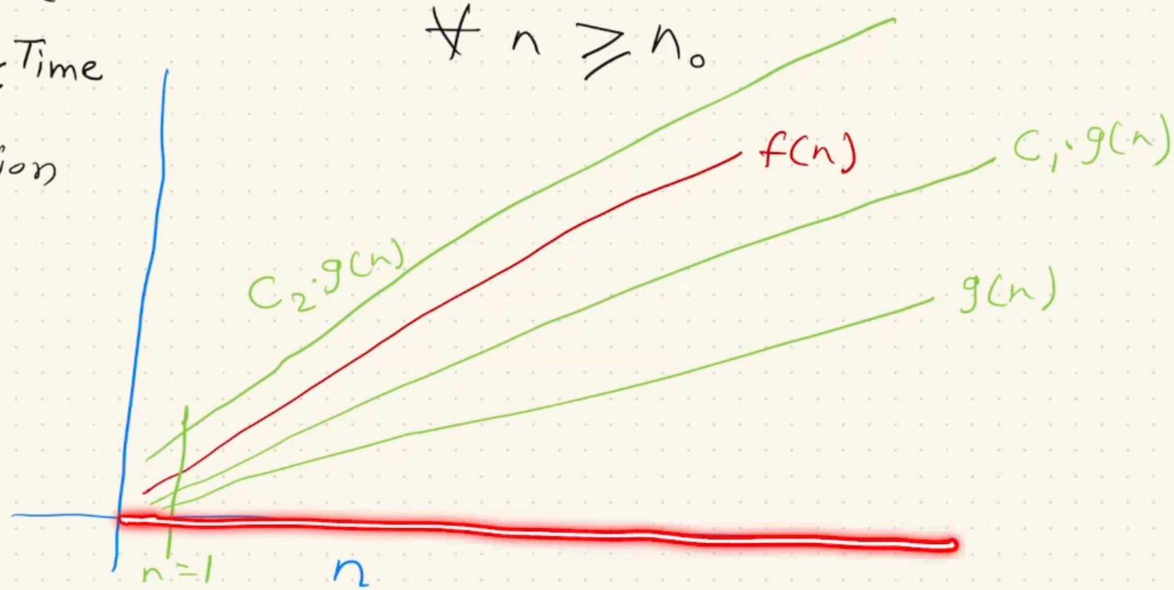
$c_1 \quad c_2 \quad n_0$

Maps problem size to resource consumption

Time

$0 \leqslant c_1 \cdot g(n) \leqslant f(n) \leqslant c_2 \cdot g(n)$

$\forall n \geqslant n_0$



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$f(n) = n^2 + 2n + 5$ $g(n) = n^2$ $c_1 = 1$ $c_2 = 8$ $n_0 = 1$

n	$f(n)$	$g(n)$	$c_1 \cdot g(n)$	$c_2 \cdot g(n)$
0	5	0	0	0
1	8	1	1	8
2	13	4	4	32
3	20	9	9	72
4	29	16	16	128
5	40	25	25	200

$f(n) \in \Theta(g(n))$ $c_1 = 1$ $c_2 = 8$ $n_0 = 1$

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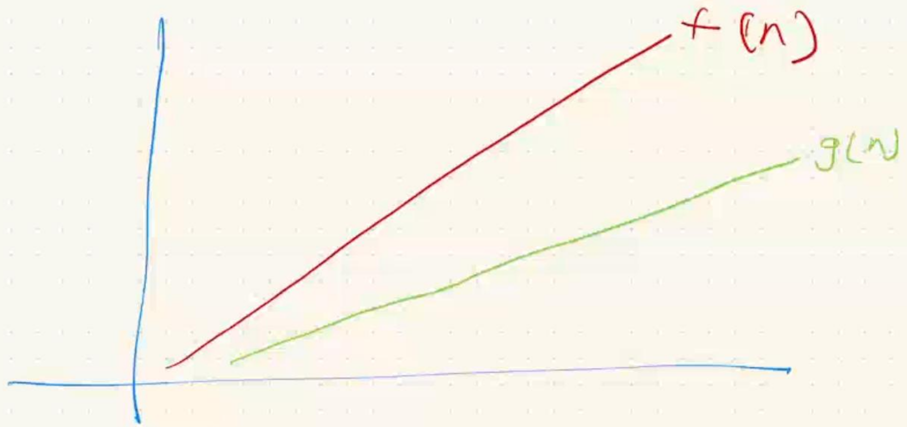
$f(n) \in O(g(n))$

$c \quad n_0$

$$0 \leq f(n) \leq c \cdot g(n) \quad \forall n \geq n_0$$



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$f(n) = n^2 + 5n + 2 \qquad g(n) = n^2 \qquad f(n) \in O(g(n))\ ?$

$c \qquad n_0$

$f(n) = 5n + 2 \qquad g(n) = n^2 \qquad c = 2 \qquad n_0 = 3$

n	$5n+2$	n^2	$2 \cdot n^2$	$0.5\,n^2$
0	2	0	0	0
1	7	1	2	0.5
2	12	4	8	2
3	17	9	18	4.5
4	22	16	32	8
5	27	25	50	12.5
6	32	36		18

$c = 0.5 \qquad n_0 =$

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Θ	O	Ω
asymptotic tight bound	asymptotic upper bound	asymptotic lower bound
$=$	$\leq$	$\geq$

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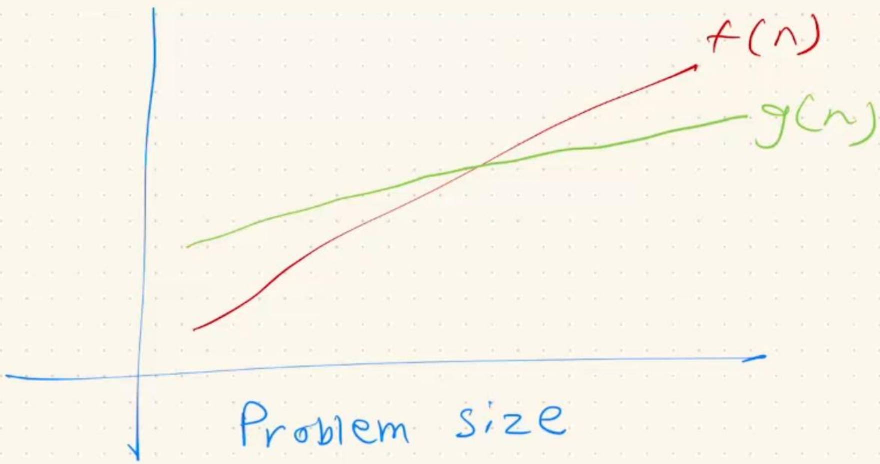
$$f(n) \in \Omega(g(n))$$

$$c \quad n_0$$

$$0 \leq c \cdot g(n) \leq f(n) \quad \forall \; n \geq n_0$$



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$f(n) = n^2 + 5n + 2 \quad g(n) = n^2 \quad f(n) \in \Omega(g(n))$?

$c = 1 \quad n_0 = 0$

$f(n) \geq c\, g(n)$

$c = 500$

12 of 12

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04 Algorithm Analysis

Transitivity:

$A : B, \quad B : C \longrightarrow A : C$

$f(n) \in \Theta(g(n)), \quad g(n) \in \Theta(h(n)) \longrightarrow f(n) \in \Theta(h(n))$

$\quad O \qquad\qquad\qquad O \qquad\qquad\qquad O$

$\quad \Omega \qquad\qquad\qquad \Omega \qquad\qquad\qquad \Omega$

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Reflexivity:

A : A

$f(n) \in \Theta(f(n))$

$f(n) \in O(f(n))$

$f(n) \in \Omega(f(n))$

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Symmetry:

$$A ; B \longleftrightarrow B ; A$$

$$f(n) \in \Theta(g(n)) \longleftrightarrow g(n) \in \Theta(f(n))$$

$$\downarrow \qquad \qquad \qquad \qquad \uparrow$$

$$0 \leq c_1 \cdot g(n) \leq f(n) \leq c_2 \cdot g(n) \quad \forall n \geq n_0$$

$$g(n) \leq \frac{f(n)}{c_1} \qquad \frac{f(n)}{c_2} \leq g(n) \quad \forall n \geq n_0$$

$$1/c_1 = c_1' \qquad 1/c_2 = c_2'$$

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$$f(n) \in O(g(n)) \longleftrightarrow g(n) \in O(f(n))$$

$$\Omega \qquad\qquad\qquad \Omega$$

Counter example

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Fibonacci Numbers

$fib(1) = 0 \quad fib(2) = 1 \quad fib(n) = fib(n-1) + fib(n-2)$

FibR(n)

```
if(n==1){
    return 0
}
if (n== 2){
    return 1
}
answer=FibR(n-1) + FibR(n-2)
return (answer)
```

$T(n) = T(n-1) + T(n-2)$

$T(n) \simeq (1.6)^n$

n	Fib(n)
1	0
2	1
3	1
4	2
5	3
6	5
7	8
8	13

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```
FibS( n){
    if(n==1){
        return 0
    }
    if (n== 2){
        return 1
    }
    fibn1 = 1      fib(n-1)
    fibn2 = 0      fib(n-2)
    for(curr=3, curr<=n, curr=curr+1){
        answer= fibn1 + fibn2
        fibn2 = fibn1
    }   fibn1 = answer
```

To compute n^{th} number

Start from 3^{rd} number

and then compute 4^{th}

then 5^{th}

⋮

till you reach n^{th}

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```
FibS( n){
    if(n==1){
        return 0
    }
    if (n== 2){
        return 1
    }
    fibn1 = 1        <- fib(n-1)
    fibn2 = 0        <- fib (n-2)
    for(curr=3, curr ≤ n, curr=curr+1){
        answer = fibn1 + fibn2
        fibn2 = fibn1
        fibn1 = answer
    }
    return answer
```

To compute n^{th} number

Start from 3^{rd} number

and then compute 4^{th}

then 5^{th}

⋮

till you reach n^{th}

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```
FibS ( n) {
    if(n==1){
        return 0
    }
    if (n== 2){
        return 1
    }
    fibn1 = 1
    fibn2 = 0
    for(curr=3, curr≤ n, curr=curr+1){
        answer= fibn1 + fibn2
        fibn2 = fibn1
        fibn1 = answer
    }
    return answer
}
```

c_1

$c_2 \cdot n$

c_3

fib(n-1)

fib(n-2)

To compute n^{th} number

Start from 3^{rd} number

and then compute 4^{th}

then 5^{th}

⋮

till you reach n^{th}

$T(n) \in \Theta(n)$

$$T(n) = c_1 + \underline{c_2 \cdot n} + c_3$$

$c_2 \cdot (n-2)$

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$(1.6)^5 = 10$

n	fib S	fib R
1	1	$(1.6)^1 \rightarrow 1.6$
10	10	$(1.6)^{10} \rightarrow 10^2 \rightarrow 10^{-8}$ sec 10^{10} $\frac{\text{ins}}{\text{second}}$
		$(1.6)^{100} \rightarrow 10^{20} \rightarrow 10^{10}$ sec $\rightarrow 10 \times 10^9$
100	100	$(1.6)^{1000} \rightarrow 10^{200} \rightarrow 10^{190}$ sec
1000	1000	$(1.6)^{10000} \rightarrow 10^{2000} \rightarrow 10^{1990}$ sec
10 000	10 000	

$\downarrow$

Less than 1 sec

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Abstractions

- Bits → Digital circuit
- Files → Secondary storage
- Machine code → Operations by Processor
- Basic data types → Data handled by processor

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05 ADT

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- Ease of understanding
- Independence from implementation
- Separation of concerns

  specification and implementation

- Ability to build more abstraction

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GUNJAN DHANUKA

SR SHUBHRADEEP ROY

PK PRADEEP KUMAR

SIDDHARTH GAUR

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05 ADT

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Abstract Data Type (ADT)

- Data
- Operations

int   Integer

Data → 16 / 32 / 64 bits → Circuits ↑ Transister ↑

Operations → +, −, ×, /, ++, ==

- Access to data is only through operations

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SHUBHRADEEP ROY

PRADEEP KUMAR

SIDDHARTH GAUR

ST

Abstract Data Type (ADT)

- Data
- Operations

int — Integer

Data → 16 / 32 / 64 bits → Circuits ↑ Transister ↑

Operations → +, -, x, /, ++, ==

- Access to data is only through operations
- Implementation details need not be shared
- Naturally translates to OOP languages

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05 ADT

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Array ADT

Data: < index, value >

Collection of pairs

Operations:

createNew (capacity, type)

StoreValue (index, val)

accessValue (index)

searchValue (value)

initArray (value)

- Store same type of data
- Contiguous storage
- fixed storage
- Access element with index
- Change element at any index
- Structure is fixed at the time of creation
- We can have array of arrays
- Most of the programming languages provide it

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05 ADT

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Array ADT

Data: <index, value>

Collection of pairs

Operations:

createNew (capacity, type)

StoreValue (index, val)

accessValue (index) 5 → 2.9

searchValue (value)

initArray (value)

- Store same type of data
- Contiguous storage
- fixed storage
- Access element with index
- Change element at any index
- Structure is fixed at the time of creation
- We can have array of arrays
- Most of the programming languages provide it

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05 ADT

Array ADT

Data: < index, value >

Collection of pairs

Operations:

createNew (capacity, type)

StoreValue (index , val)

accessValue (index)

searchValue (value)

initArray (value)

- ✓ · Store same type of data
- ✗ · Contiguous Storage
- ✗ · fixed Storage
- ✓ · Access element with index
- ✓ · Change element at any index
- ✗ · Structure is fixed at the time of creation
- ✓ · We can have array of arrays
- · Most of the programming languages provide it

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