CSE 121 Lesson 16:
Arrays and 2D Arrays

Matt Wang

Spring 2024

TAs:	Andy	Anju	Archit	Arkita	Autumn	Christian
	Hannah H	Hannah S	Heather	Hibbah	Janvi	Jessie
	Jonus	Julia	Luke	Maria	Mia	Ritesh
	Shayna	Simon	Trey	Vidhi	Vivian	Gumball?

sli.do #cse121-16

Today's playlist:
CSE 121 lecture beats 24sp

Announcements, Reminders

- **Quiz 2 tomorrow!**

- Programming Assignment 3 releasing later today – last assignment!
  - Extending P3's planned deadline to **Thursday** next week (May 30th)
  - But, can only resubmit for R7
    (as feedback will <u>not</u> be released the following Tuesday)

- IPL has special hours for the next week – <u>see Ed post!</u>

- Final Exam: **Wednesday, June 5th from 2:30-4:20 in KNE 120**
  - <u>Left-Handed Seating Requests Form</u>, closes end-of-day Tuesday, May 28th

Final Exam Details (1/2)

- Final Exam: **Wednesday, June 5th from 2:30-4:20 in KNE 120**
- In-person, on paper, with assigned seating
- No collaboration – should be completed individually
- <u>Not open book</u>
  - We will provide you one "reference sheet", and
  - You may bring **one 8.5x11-inch** page of notes, handwritten or typed, double-sided
- Will have 6 problems, all similar in style to the quizzes
- Focus is on behavior (not code style) – minor syntax errors are allowed

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Final Exam Details (2/2)

- Next week will be focused on Final Exam review and preparation

- Many resources will be available, including:
  - dedicated lecture time for final exam review!
  - dedicated section time for final exam review!
  - multiple previous <u>actual</u> finals + practice finals
  - final exam review session (details TBD)

- Reminder: IPL will <u>not</u> be open during finals week, so plan ahead!

- More details on Friday (+ on course website)
  - (expect an announcement post from me, after the quiz)

Poll in with your answer!

```java
public static void main(String[] args) {
    int x = 0;
    int[] a = new int[4];
    x++;

    mystery(x, a);
    System.out.println(x + " " + Arrays.toString(a));

    x++;
    mystery(x, a);
    System.out.println(x + " " + Arrays.toString(a));
}

public static void mystery(int x, int[] a) {
    x++;
    a[x]++;
    System.out.println(x + " " + Arrays.toString(a));
}
```

Four lines of output would be produced by this code. What would those four lines be?

Poll in with your answer!

```java
public static void main(String[] args) {
    int x = 0;
    int[] a = new int[4];
    x++;

    mystery(x, a);
    System.out.println(x + " " + Arrays.toString(a));


    x++;
    mystery(x, a);
    System.out.println(x + " " + Arrays.toString(a));
}

public static void mystery(int x, int[] a) {
    x++;
    a[x]++;
    System.out.println(x + " " + Arrays.toString(a));
}
```

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(PCM) 2D Arrays (1/3)

`int[][]` `a` `= new int[4][3];`

type   name   array creation code

An array of arrays!

- The *ElementType* of the array is another array itself!
  - Your first example of "nested data structures"
    - There will be more in CSE 122!
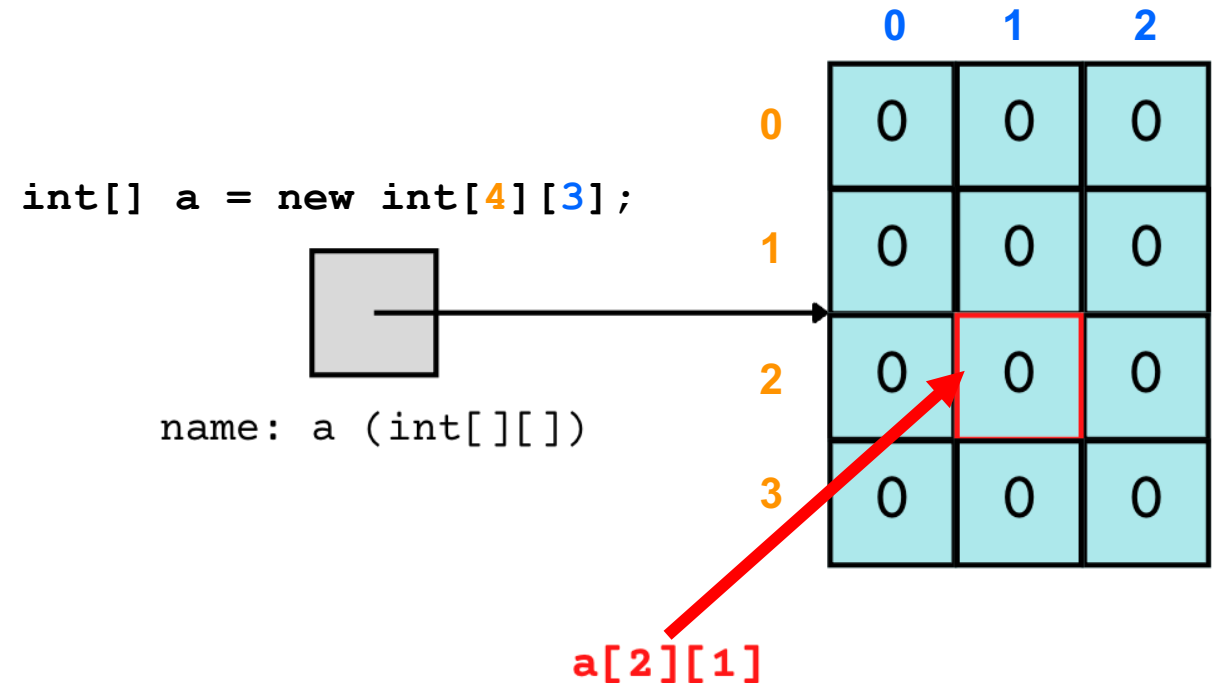
```
int[][]          double[][]      String[][]

      boolean[][]         char[][]
```

(PCM) 2D Arrays (2/3)

An array of arrays!

The two dimensions are "rows" and "columns"

```
int[] a = new int[4][3];
```

name: a (int[][])

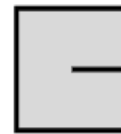|	0	1	2
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0

a[2][1]

(PCM) 2D Arrays (3/3)

A slightly more accurate view...

```
int[] a = new int[4][3];
```

name: a (int[][])

reference semantics
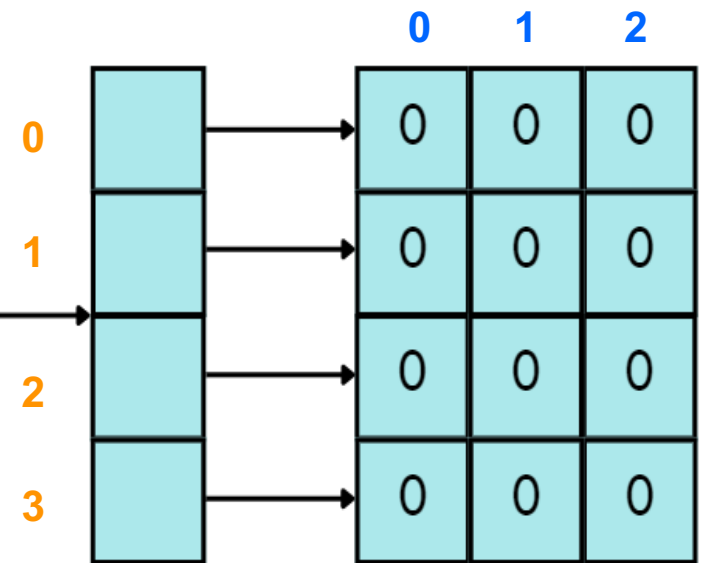
(PCM) 2D Array Traversals

for each row…

```
for (int i = 0; i < list.length; i++) {
    for (int j = 0; j < list[i].length; j++) {
        // do something with list[i][j]
    }
}
```

for each element within a row…

Arrays Utility Class

Method	Description
`Arrays.toString(array);`	Returns a `String` representing the array, such as `"[10, 30, -25, 17]"`
`Arrays.fill(array, value);`	Sets every element to the given value
`Arrays.equals(array1, array2);`	Returns `true` if the two arrays contain the same elements in the same order
`Arrays.deepToString(array);`	Returns a `String` representing the array; if the array contains other arrays as elements, the `String` represents their contents, and so on. For example, `"[[99, 151], [30, 5]]"`
`Arrays.deepEquals(array1, array2);`	Returns `true` if the two arrays contain the same elements in the same order; if the array(s) contain other arrays as elements, their contents are tested for equality, and so on.

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Applications of 2D Arrays

- **Matrices**
  - Useful in various applications requiring complex math!
  - Fundamental to machine learning & AI
  - P3 is a real-life application of this!

- Board games
  - e.g., chess/checkerboard, tic tac toe, sudoku

- Representing information in a grid or table
  - e.g., scorekeeping, gradebook, census data

- Image processing

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

→

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matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+
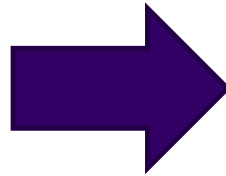
70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

`i: 0`
`j: 0`

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+
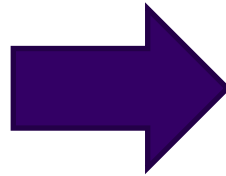
70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

`i: 0`
`j: 0`
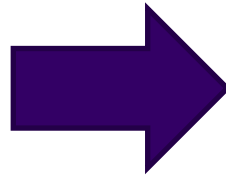
93				

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

```
i: 0
j: 1
```

→
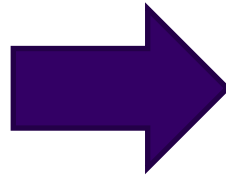
93	169			

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+
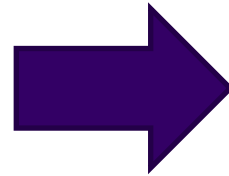
70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

i: 0
j: 2

93	169	84		

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

i: 0
j: 3
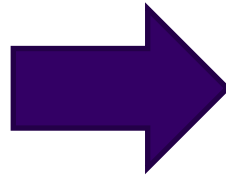
93	169	84	83	

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

i: 0
j: 4

→
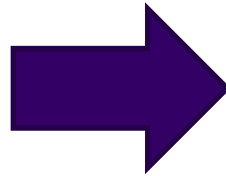
93	169	84	83	103

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+
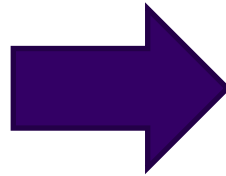
70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

`i: 1`
`j: 0`

93	169	84	83	103
136				

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

i: 1
j: 1
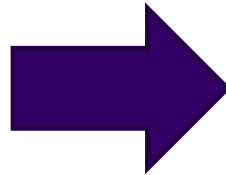
93	169	84	83	103
136	115			

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

```
i: 1
j: 2
```
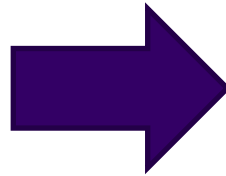
93	169	84	83	103
136	115	91		

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

i: 1
j: 3
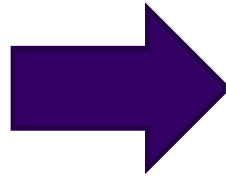
93	169	84	83	103
136	115	91	143	

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

```
i: 1
j: 4
```

➡
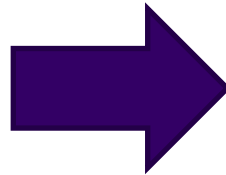
93	169	84	83	103
136	115	91	143	81

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

```
i: 2
j: 0
```

93	169	84	83	103
136	115	91	143	81
119				

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

i: 2
j: 1
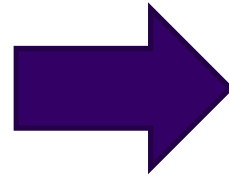
93	169	84	83	103
136	115	91	143	81
119	77			

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

i: 2
j: 2

➡
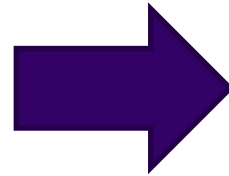
93	169	84	83	103
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matrixAdd

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70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

i: 2
j: 3

→

93	169	84	83	103
136	115	91	143	81
119	77	98	105	

matrixAdd

23	96	18	4	64
45	40	18	44	34
92	13	77	71	12

+

70	73	66	79	39
91	75	73	99	47
27	64	21	34	1

```
i: 2
j: 4
```
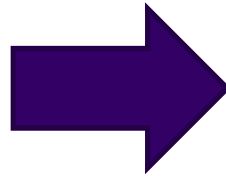
93	169	84	83	103
136	115	91	143	81
119	77	98	105	13

matrixAdd

23	96	18	4	64
45	40	18	44	34
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70	73	66	79	39
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➡

93	169	84	83	103
136	115	91	143	81
119	77	98	105	13

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(2D)ays Above Average: readData()

```
How many days' data would you like to input? 3
Next day's data:
    Temperature in Seattle? 44
    Temperature in Tacoma? 40
    Temperature in Bothell? 43
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 40
    Temperature in Bothell? 44
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 41
    Temperature in Bothell? 43
…
```

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3	42	41	43

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(2D)ays Above Average: readData()

How many days' data would you like to input? **3**
Next day's data:
  Temperature in Seattle? **44**
  Temperature in Tacoma? **40**
  Temperature in Bothell? **43**
Next day's data:
  Temperature in Seattle? **42**
  Temperature in Tacoma? **40**
  Temperature in Bothell? **44**
Next day's data:
  Temperature in Seattle? **42**
  Temperature in Tacoma? **41**
  Temperature in Bothell? **43**
…

	Seattle	Tacoma	Bothell
1	44		
2			
3			

(2D)ays Above Average: readData()

```
How many days' data would you like to input? 3
Next day's data:
    Temperature in Seattle? 44
    Temperature in Tacoma? 40
    Temperature in Bothell? 43
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 40
    Temperature in Bothell? 44
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 41
    Temperature in Bothell? 43
…
```

	Seattle	Tacoma	Bothell
1	44	40	
2			
3			

(2D)ays Above Average: readData()

```
How many days' data would you like to input? 3
Next day's data:
    Temperature in Seattle? 44
    Temperature in Tacoma? 40
    Temperature in Bothell? 43
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 40
    Temperature in Bothell? 44
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 41
    Temperature in Bothell? 43
…
```

	Seattle	Tacoma	Bothell
1	44	40	43
2			
3			

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(2D)ays Above Average: readData()

```
How many days' data would you like to input? 3
Next day's data:
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    Temperature in Tacoma? 40
    Temperature in Bothell? 43
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 40
    Temperature in Bothell? 44
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 41
    Temperature in Bothell? 43
…
```

	Seattle	Tacoma	Bothell
1	44	40	43
2	42		
3			

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(2D)ays Above Average: readData()

```
How many days' data would you like to input? 3
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    Temperature in Seattle? 42
    Temperature in Tacoma? 40
    Temperature in Bothell? 44
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 41
    Temperature in Bothell? 43
…
```

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	
3			

(2D)ays Above Average: readData()

How many days' data would you like to input? **3**
Next day's data:
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   Temperature in Tacoma? **40**
   Temperature in Bothell? **43**
Next day's data:
   Temperature in Seattle? **42**
   Temperature in Tacoma? **40**
   Temperature in Bothell? **44**
Next day's data:
   Temperature in Seattle? **42**
   Temperature in Tacoma? **41**
   Temperature in Bothell? **43**
…

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3			

(2D)ays Above Average: readData()

How many days' data would you like to input? **3**
Next day's data:
    Temperature in Seattle? **44**
    Temperature in Tacoma? **40**
    Temperature in Bothell? **43**
Next day's data:
    Temperature in Seattle? **42**
    Temperature in Tacoma? **40**
    Temperature in Bothell? **44**
Next day's data:
    Temperature in Seattle? **42**
    Temperature in Tacoma? **41**
    Temperature in Bothell? **43**
…

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3	42		

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(2D)ays Above Average: readData()

```
How many days' data would you like to input? 3
Next day's data:
    Temperature in Seattle? 44
    Temperature in Tacoma? 40
    Temperature in Bothell? 43
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 40
    Temperature in Bothell? 44
Next day's data:
    Temperature in Seattle? 42
    Temperature in Tacoma? 41
    Temperature in Bothell? 43
…
```

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3	42	41	

(2D)ays Above Average: readData()

How many days' data would you like to input? **3**
Next day's data:
   Temperature in Seattle? **44**
   Temperature in Tacoma? **40**
   Temperature in Bothell? **43**
Next day's data:
   Temperature in Seattle? **42**
   Temperature in Tacoma? **40**
   Temperature in Bothell? **44**
Next day's data:
   Temperature in Seattle? **42**
   Temperature in Tacoma? **41**
   Temperature in Bothell? **43**

…

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3	42	41	43

(2D)ays Above Average: computeAverages()

	Seattle	Tacoma	Bothell
1	44	40	43
2	42	40	44
3	42	41	43

42.667	40.333	43.333

Average of Seattle
temperatures
(44 + 42 + 42) / 3