CSE 121 Lesson 16:
Arrays and 2D Arrays

Matt Wang
Spring 2024
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 not be released the following Tuesday)

• **IPL has special hours for the next week – see Ed post!**

• **Final Exam: Wednesday, June 5th from 2:30-4:20 in KNE 120**
  • [Left-Handed Seating Requests Form](#), 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
- **Not open book**
  - 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
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 actual finals + practice finals
  • final exam review session (details TBD)
• Reminder: IPL will not be open during finals week, so plan ahead!
• More details on Friday (+ on course website)
  • (expect an announcement post from me, after the quiz)
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));
}
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));
}
```
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[][] a = new int[4][3];
```

```
int[][] double[][] String[][]
boolean[][] char[][]
```
(PCM) **2D Arrays (2/3)**

An array of arrays!

The two dimensions are "rows" and "columns"
A slightly more accurate view...

reference semantics
(PCM) 2D Array Traversals

for each row...

```java
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

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
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</table>
| 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. |
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

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j: 0
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\[ i: 0 \]
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### matrixAdd

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### Example

- **i**: 0
- **j**: 1

#### 1

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\[\begin{array}{ccc}
93 & 169 &  84 \\
\end{array}\]
matrixAdd

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$\text{i: 0}$  

$\text{j: 3}$  

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$\begin{array}{c}
93 \quad 169 \quad 84 \quad 83 \quad 103 \\
\end{array}$

$\begin{array}{c}
91 \\
75 \\
73 \\
99 \\
47 \\
\end{array}$

$\begin{array}{c}
27 \\
64 \\
21 \\
34 \\
1 \\
\end{array}$

$i: 0$

$j: 4$
matrixAdd

\[
\begin{array}{ccccc}
23 & 96 & 18 & 4 & 64 \\
45 & 40 & 18 & 44 & 34 \\
92 & 13 & 77 & 71 & 12 \\
\end{array}
\]

\[
\begin{array}{ccccc}
70 & 73 & 66 & 79 & 39 \\
91 & 75 & 73 & 99 & 47 \\
27 & 64 & 21 & 34 & 1 \\
\end{array}
\]

\[
\begin{array}{cccc]
93 & 169 & 84 & 83 & 103 \\
136 & 81 & 119 & 77 & 98 & 105 & 13 & 20 \\
\end{array}
\]

\[
i: 1 \\
j: 0
\]
### matrixAdd

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### i: 1

### j: 1

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PAUL G. ALLEN SCHOOL OF COMPUTER SCIENCE & ENGINEERING
### matrixAdd

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### Example

- **i**: 1
- **j**: 2

Add the corresponding elements of the two matrices:

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Result matrix:

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matrixAdd

\[
\begin{bmatrix}
23 & 96 & 18 & 4 & 64 \\
45 & 40 & 18 & 44 & 34 \\
92 & 13 & 77 & 71 & 12 \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
70 & 73 & 66 & 79 & 39 \\
91 & 75 & 73 & 99 & 47 \\
27 & 64 & 21 & 34 & 1 \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
93 & 169 & 84 & 83 & 103 \\
136 & 115 & 91 & 143 & \\
\end{bmatrix}
\]
matrixAdd

\[
\begin{array}{cccc}
23 & 96 & 18 & 4 \\
45 & 40 & 18 & 44 \\
92 & 13 & 77 & 71 \\
\end{array}
\]

\[
\begin{array}{cccc}
70 & 73 & 66 & 79 \\
91 & 75 & 73 & 99 \\
27 & 64 & 21 & 34 \\
\end{array}
\]

\[
\begin{array}{cccc}
i: 1 \\
93 & 169 & 84 & 83 \\
136 & 115 & 91 & 143 \\
\end{array}
\]

\[
\begin{array}{cccc}
j: 4 \\
92 & 13 & 77 & 71 \\
136 & 115 & 91 & 143 \\
\end{array}
\]

\[
\begin{array}{cccc}
93 & 169 & 84 & 83 \\
136 & 115 & 91 & 143 \\
\end{array}
\]
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\[ i: 2 \]
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PAUL G. ALLEN SCHOOL  
OF COMPUTER SCIENCE & ENGINEERING  

25
## matrixAdd

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\[ \begin{array}{c}
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\text{j: 1}
\end{array} \]

\[\begin{array}{ccccc}
93 & 169 & 84 & 83 & 103 \\
136 & 115 & 91 & 143 & 81 \\
119 & 77 &   &   &   \\
\end{array}\]

\[\begin{array}{c}
70 \\
91 \\
27
\end{array}\]

\[\begin{array}{c}
73 \\
75 \\
64
\end{array}\]

\[\begin{array}{c}
66 \\
73 \\
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\end{array}\]

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\end{array}\]

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136 & 115 & 91 & 143 & 81 \\
119 & 77 & 98 & 105 & \\
\end{array}
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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

...
(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

...
(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

…

<table>
<thead>
<tr>
<th></th>
<th>Seattle</th>
<th>Tacoma</th>
<th>Bothell</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>44</td>
<td>40</td>
<td></td>
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(2D)ays Above Average: readData()

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...
(2D)ays Above Average: \texttt{readData()}

How many days' data would you like to input? \texttt{3}

Next day's data:
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  - Temperature in Tacoma? \texttt{40}
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Next day's data:
  - Temperature in Seattle? \texttt{42}
  - Temperature in Tacoma? \texttt{40}
  - Temperature in Bothell? \texttt{44}

Next day's data:
  - Temperature in Seattle? \texttt{42}
  - Temperature in Tacoma? \texttt{41}
  - Temperature in Bothell? \texttt{43}

\[\begin{array}{ccc}
1 & 44 & 40 & 43 \\
2 & 42 & & \\
3 & & & \\
\end{array}\]
How many days' data would you like to input? 3

Next day's data:
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(2D)ays Above Average: `readData()`

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...
(2D)ays Above Average: `computeAverages()`

How many days' data would you like to input? 3...

The average values for each location were

\[ [42.666666666666664, 40.333333333333336, 43.333333333333336] \]

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Average of Seattle temperatures

\[
(44 + 42 + 42) / 3
\]