PHYS11 CH: Two Dimensional Arrays

Data Structures and Memory Organization

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Outline

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Learning Objectives

By the end of this lesson, you will be able to:

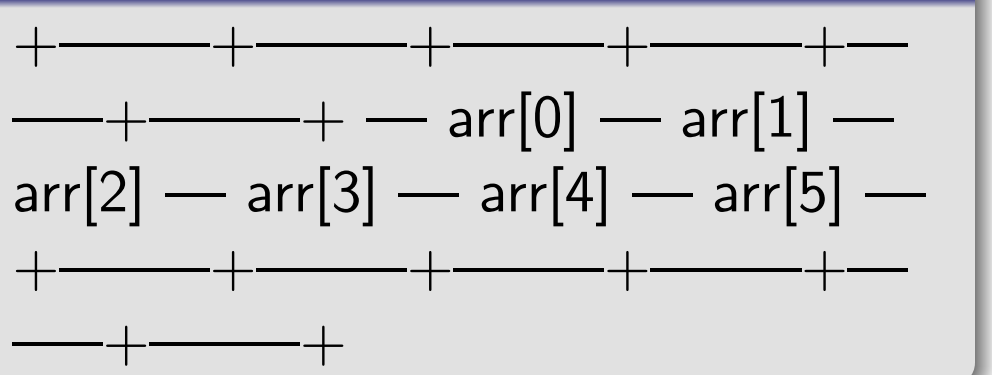
- Define and declare two-dimensional arrays in C++
- Understand how 2D arrays are represented in memory
- Access and manipulate elements in a 2D array
- Implement functions that work with 2D arrays
- Solve problems using 2D arrays

One Dimensional Arrays - Review

Declaration

```
int arr[6];
```

Memory Representation



- A one-dimensional array stores elements in a single row
- Each element is accessed with a single index
- Elements are stored contiguously in memory

Two Dimensional Arrays

Declaration

```
int arr[3][6];
```

We can think of this as:

- 3 rows of arrays
- Each row contains 6 elements
- Total of $3 \times 6 = 18$ elements

Memory Representation

```
[basicstyle=] Memory layout
(row-major order):  arr[0][0]
arr[0][1] arr[0][2] arr[0][3]
arr[0][4] arr[0][5] arr[1][0]
arr[1][1] arr[1][2] arr[1][3]
arr[1][4] arr[1][5] arr[2][0]
arr[2][1] arr[2][2] arr[2][3]
arr[2][4] arr[2][5]
```

Accessing 2D Array Elements

- Elements are accessed using two indices: [row][column]
- The first index (row) ranges from 0 to rows-1
- The second index (column) ranges from 0 to columns-1

Example

For `arr[3][6]`:

- Valid indices range from [0][0] to [2][5]
- `arr[1][4]` accesses the element in the 2nd row, 5th column
- `arr[0][2] = 42;` assigns the value 42 to the element in the 1st row, 3rd column

Be Careful!

`arr[3][6]` is an out-of-bounds access and will lead to undefined behavior!

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Limitations of 2D Arrays in C++

Important Limitation

When passing 2D arrays to functions, you **must** specify the number of columns!

Invalid

```
int someFunction(int arr[][]);
```

```
int someFunction(int arr[][COLS]);
```

- The number of columns must be a constant value
- The first dimension (rows) can be unspecified
- Typically, use a global constant or #define for COLS

Function Parameter Syntax

Function Declaration Examples

// Prints a 2D array void printArr2d(int arr[][NUM$_C$OLS], *introws*);
// Calculates the sum of elements in a specific row int rowSum(int arr[][NUM$_C$OLS], *introwNum*);
// Finds the maximum value in a specific row int rowMax(int arr[][NUM$_C$OLS], *introwNum*);
// Finds the row with the largest sum int maxRowSum(int arr[][NUM$_C$OLS], *introws*);

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Printing a 2D Array

Function Declaration

[basicstyle=] `void printArr2d(int arr[][NUM_COLS], int rows);` /* *Parameters* : *arr*, *a 2D array of size rows x cols Behavior* : *uses cout to output the array columns as a comma separated list for each row* */

Implementation

[basicstyle=] `void printArr2d(int arr[][NUM_COLS], int rows) for(int i = 0; i < ro`

Calculating Row Sum

Function Declaration

[basicstyle=] `int rowSum(int arr[][NUM_C OLS], int rowNum); /* Finds the sum of the elements of row Num Parame arr[][NUM_C OLS] - array with at least row Num + 1 rows row Num - the row to find the sum from 0 to number of rows - 1 */`

Implementation

[basicstyle=] `int rowSum(int arr[][NUM_C OLS], int rowNum) int sum = 0; for (int j = 0; j < NUM_C OLS; j++) sum += arr[rowNum][j]; return sum;`

Finding Row Maximum

Function Declaration

[basicstyle=] `int rowMax(int arr[][NUM_COLS], int rowNum);` /* Finds the largest element in the rowNum row Para
arr[][NUM_COLS] - array with at least rowNum+1 rows rowNum - the row to find largest value in the rowNum row No
rows are from 0 to number of rows - 1 */

Implementation

[basicstyle=] `int rowMax(int arr[][NUM_COLS], int rowNum) int max = arr[r
for (int j = 1; j < NUM_COLS; j + +) if (arr[rowNum][j] > max) max = arr[rowN
return max;`

Finding Maximum Row Sum

Function Declaration

[basicstyle=] `int maxRowSum(int arr[][NUM_COLS], int rows);` /* Finds the largest row sum Parameters : arr[][NUM_COLS] – 2D array of size rows * NUM_COLS row – the total number of rows */

Implementation

[basicstyle=] `int maxRowSum(int arr[][NUM_COLS], int rows)int maxSum = row`

```
for (int i = 1; i < rows; i++)
int currentSum = rowSum(arr, i);
if (currentSum > maxSum)  maxSum =
currentSum;
return maxSum;
```

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Treasure Map Problem

Problem Description

Given a grid (2D array) of numbers representing treasures:

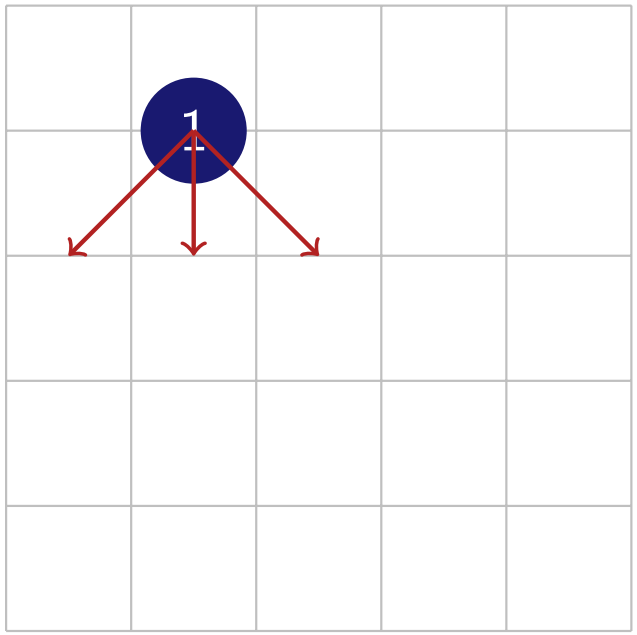
- Start at any cell in the top row
- Move down, but can only move to one of the three adjacent cells in the next row
- End at any cell in the bottom row
- Find the path with the maximum treasure sum

[basicstyle=] +---+---+---+---+---+ | 8 | 9 | 6 | 8 | 2 | +---+---+---+---+---+ | 1 | 8 | 7 | 6 | 3 | +---+---+---+---+---+ | 5 | 3 | 1 |10 | 5 | +---+---+---+---+---+ | 9 | 6 | 8 | 4 | 9 | +---+---+---+---+---+ | 7 | 1 | 9 | 7 | 7 | +---+---+---+---+---+ | 7 | 9 | 5 | 9 | 8 | +---+---+---+---+---+

Movement Rules in Treasure Map

Rules for Movement

- Start at any cell in the top row
- From a cell [i][j], can move to:
  - i+1 [j-1] (diagonal left)
  - i+1 [j] (directly below)
  - i+1 [j+1] (diagonal right)
- If at edge, can't move diagonally outside grid
- End at any cell in the bottom row



Maximum Path Solution

[basicstyle=]

```
+---+---+---+---+---+ | 8 |*9*|
6 | 8 | 2 | * = Path
+---+---+---+---+---+ | 1 | 8
|*7*| 6 | 3 |
+---+---+---+---+---+ | 5 | 3 |
1 |*10*| 5 |
+---+---+---+---+---+ | 9 | 6
|*8*| 4 | 9 |
+---+---+---+---+---+ | 7 | 1
|*9*| 7 | 7 |
+---+---+---+---+---+ | 7 |*9*|
5 | 9 | 8 |
+---+---+---+---+---+
```

Maximum Path: $9 + 7 + 10 + 8 + 9 + 9 = 52$

Dynamic Programming Approach

- Start with the top row (base case)
- For each row, calculate cumulative sums
- At each cell, choose the maximum of three possible paths from above
- Continue until we reach the bottom row
- Find the maximum value in the bottom row

Cumulative Sums Calculation

[basicstyle=]

```
+-----+-----+-----+-----+-----+ |
8 | 9 | 6 | 8 | 2 |
+-----+-----+-----+-----+-----+ |
1+9 | 8+9 | 7+9 | 6+8 | 3+8 |
+-----+-----+-----+-----+-----+ |
5+17 | 3+17 | 18 | 26 | 19 |
+-----+-----+-----+-----+-----+ |
31 | 28 | 34 | 30 | 35 |
+-----+-----+-----+-----+-----+ |
38 | 35 | 43 | 42 | 42 |
+-----+-----+-----+-----+-----+ |
45 | 52 | 48 | 52 | 50 |
+-----+-----+-----+-----+-----+
```

Calculation Method

For each cell [i][j] (except first row):

$$sum[i][j] = arr[i][j] + max(sum[i-1][j-1], sum[i-1][j], sum[i-1][j+1])$$

With boundary checks for edges.

Summary

Key Concepts

- Two-dimensional arrays store data in a grid-like structure
- Accessed using two indices: [row][column]
- When passing to functions, column size must be specified
- Common operations:
  - Traversing row by row
  - Finding row sums and maximums
  - Dynamic programming for pathfinding problems

Remember

- Valid indices range from [0][0] to [rows-1][cols-1]
- Always check array bounds to prevent errors
- Use descriptive function parameters for clarity