Multidimensional Arrays

ENEE 140

Prof. Tudor Dumitraș
Assistant Professor, ECE
University of Maryland, College Park

http://ter.ps/enee140

Today's Lecture

- Where we've been
  - Scalar data types (`int, long, float, double, char`)
  - Basic control flow (`while` and `if`)
  - Functions
  - Random number generation
  - Arrays and strings
- Where we're going today
  - Multidimensional arrays
- Where we're going next
  - Sorting

2

Nested Loops

- You can nest loops

```
for (i=1; i<=3; i++) {
     for (j=1; j<=3; j++) {
           printf("%dx%d=%2d\t", i, j, i*j);
     }
     printf("\n");       // ready for next line
}
```

- Output

```
1x1= 1     1x2= 2     1x3= 3
2x1= 2     2x2= 4     2x3= 6
3x1= 3     3x2= 6     3x3= 9
```

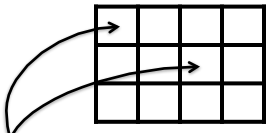
3

Multi-Dimensional Arrays

- Two-dimensional arrays

`int a[3][4];` int array with 3 rows and 4 columns (12 elements)

  - Think of this as 3 arrays with 4 elements each



- Working with 2D arrays

`a[0][0] = 0;` access element on first row and first column

`a[1][2] = 0;` access element on row 1 and column 2

`a[0][4] = 0;` error: index out of bounds

`a[3][0] = 0;` error: index out of bounds

  - Use 2D arrays to represent matrices

- Arrays with 3, 4, 5, etc. dimensions

`int a[2][3][4];` 3D array with 24 elements

4

Incremental Maintenance of Aggregates

- Sometimes, you must compute values that summarize multiple numbers (aggregates)
  - Examples: count, maximum, average
  - You can compute many aggregates incrementally, by updating a variable at each iteration of a loop

```
int a, count = 0, max = INT_MIN;
while (scanf("%d", &a) > 0) {
    count++;
    if (max < a)
        max = a;
}
```

must initialize the aggregates

increment count

update max

- **How should you initialize the aggregate?**

5

Backtracking

- General problem solving strategy
- Works on problems where:
  - You must search a large space of possible solutions
  - You can build the solution incrementally
  - You can check if the current partial solution is invalid (cannot possibly lead to a complete solution)
    - Typically, because it violates some constraints of the problem
  - You can enumerate all possible values for the current level (the current stage of the partial solution)

6

Backtracking: Key Idea

- Define four tests
  - all_solved: all levels have a solution
  - none_solved: none of the levels have a solution
  - end_values: have exhausted all possible values for current level
  - is_valid: the current partial solution doesn't violate any constraints
- Solve the problem incrementally
  - Start by assigning the first possible value to the first level
  - On each level, try all the possible values, in order
  - If the solution is valid (is_valid), advance to the next level; otherwise, try the next value on the current level
  - If you cannot find any suitable value for the current level (end_values) return to the previous level (backtrack) and try the next value there
  - The search ends when all levels have a solution (all_solved) – complete solution
  - The search also ends when you have backtracked until no levels have a solution (none_solved). This means that the problem cannot be solved.

7

Example: The Eight Queens Puzzle

- Place 8 queens on a chess board so that no queen threatens another queen
  - 4,426,165,368 possible positions, 92 solutions
  - Levels: rows on the chess board (cannot have more than one queen on a row)
  - Partial solution: *k* queens placed on the first *k* rows of the board so that they don't threaten each other (*k*<8)
  - all_solved: have placed 8 queens
  - none_solved: have not placed any queen
  - end_values: have exhausted all possible columns for current row
  - is_valid: no two queens on the same column or diagonal

8

Backtracking: General Design

```
Initialize position array
While ( ! all_solved )
    If ( end_values )
        Return to previous level (backtrack)
        If ( ! none_solved )
            Retrieve stored position and move to next one
        Else
            Exit loop (no more solutions to search)
    Else
        If (is_valid)
            Store position on current level
            Advance to next level
        Else
            Move to next position on current level
```

9

Review of Lecture

- What did we learn?
  - Nested loops
  - Multidimensional arrays
  - Incremental maintenance of aggregates
- Next week
  - Sorting
- Assignments for this week
  - Try to understand how the shellsort implementation from **K&R Chapter 3.5** works; read **Chapter 5.11** for how to use the library function qsort()
  - Weekly challenge: **selection_sort.c**
  - Homework: `lab12.pdf` (on http://ter.ps/enee140), due on Friday at 11:59 pm

10