Data Structures

- Holds a collection of data
  - several individual variables
    - each stores its own value
    - each is independent of the other
    - but the group can be allocated as a whole
- Many Data Structures
  - arrays, stacks, queues
  - structures
  - linked list, tree, hash table, graph, ...
- Classifications
  - Homogeneous data structure vs Heterogeneous data structure
  - Statically sized or Dynamically sized
  - Single Unit or Linked Data Structures
Array Indexing

- C provides a special syntax for accessing cells in an array
  - Allocation of space for array named `a`:
    ```c
    int a[5];
    ```
    - This creates five `int` variables "named": `a[0], a[1], a[2], a[3], a[4]`
  - To modify contents of cell #2 to 6 and cell #1 to 74:
    ```c
    a[2] = 6;
    a[1] = 74;
    ```
  - To use the contents of cell #2 and cell #1:
    ```c
    printf("value = %d\n", (a[1]-a[2]));
    ```
  - This access mechanism to the individual elements is called **array indexing**
    - In Java / C / C++, array cells are indexed beginning at 0 and going up to n-1 (n is number of cells)
    - Beware: start at 0! and end at one less than the size!!

Square Brackets: [ ] and specifying the length

- Two independent uses in C:
  - Array object creation
    ```c
    int a[10];
    ```
  - Array indexing
    ```c
    a[0]
    ```
  - Nothing in the array or about the array to indicate size of the array after it is created
  - Often we use a symbolic constant to specify the size of the array
    ```c
    #define SIZE 10
    int main(){
        int a[SIZE];
    }
    ```
Summary of Arrays

- Arrays are:
  - Sequences of cells holding values of the same type ("base type")
  - All arrays are declared and access based on that base type – all arrays are of a type

- To define an array variable:
  ```cpp
  int a[SIZE]; // an array with base type int
  ```

- To access individual array cells: use indexing
  - `a[0]`, `a[1]`, ..., `a[9]`

- Cells are just like variables:
  - They may be read: `x = a[3];`
  - They may be written: `a[2] = 7;`

A Common Programming Idiom

- To process all elements in array `a`...

- Do following:
  ```cpp
  int j = 0;
  for (j = 0; j < SIZE; j++){
    ...process the one element at `a[j]`...
  }
  ```

- Remember:
  - The lowest index is always 0
  - So use `i < SIZE`, not `i <= SIZE`
Examples

- filling an integer array using scanf
- counting elements in a character array
- adding and averaging values in a floating point array

Array Initializers

- Use curly braces and commas to list elements the array contains at startup:

```c
#define SIZE 10
int main()
    int arr1[5] = {3,2,1,8,4};
    char arr2[3] = {'J','a','n'};
    float arr3[4] = {2.4,3.6,1,5};

- If there are too many values given, compilation error is given.
- If there are too few values given, the array elements for which no value is given are assigned 0.
- If no array size is specified, it will assume you meant the exact number of the number of initializing values.
Passing Arrays as arguments

- The name of an array is a reference to (address of) the space where the array is stored
  - the [] dereference that address and add the offset determined by the value inside the brackets
  - an array argument is always a copy of that address
  - so when you modify the array argument, you do modify the original array
- An array contains elements of a base type
- The element of the array is treated like that base type if passed

Parallel Arrays

- Multiple arrays used to store related data
- index determines which person’s information:
  - student with id 91 has an 82.22 average which is calculated to be a B

<table>
<thead>
<tr>
<th>id</th>
<th>score</th>
<th>grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>67.32</td>
<td>D</td>
</tr>
<tr>
<td>94</td>
<td>92.14</td>
<td>A</td>
</tr>
<tr>
<td>12</td>
<td>87.54</td>
<td>B</td>
</tr>
<tr>
<td>91</td>
<td>82.22</td>
<td>B</td>
</tr>
<tr>
<td>14</td>
<td>74.13</td>
<td>C</td>
</tr>
<tr>
<td>99</td>
<td>58.40</td>
<td>F</td>
</tr>
<tr>
<td>42</td>
<td>80.11</td>
<td>B</td>
</tr>
</tbody>
</table>
2-Dimensional Arrays

- Declared with two dimensions of size
  - rows and columns
  - two pair of square brackets
- Indexed with two individual indexes

```c
#define ROWMAX 5
#define COLMAX 6
int main(){
    int matrix[ROWMAX][COLMAX];
    ...
    for (row = 0; row < ROWMAX; row++)
        for (col = 0; col < COLMAX; col++)
            matrix[row][col] = row + col;
    ...
}
```

Array Initializers

- Two methods
  - indicating rows and columns
  - as one list of values
- like single dimensional arrays – uninitialized values set to 0 when an initializer is used
n-Dimensional Arrays

- Three or more dimensions
  
  ```c
  #define SIZE1 5
  #define SIZE2 3
  #define SIZE3 4
  ```
  
  ```c
  int arr[SIZE1][SIZE2][SIZE3];
  for (row = 0; row < SIZE1; row++){
    for (col = 0; col < SIZE2; col++){
      for (depth = 0; depth < SIZE3; depth++){
        printf("%.2f ",arr[row][col][depth]);
      }
      printf("\n");
    }
    printf("----------------------------------------\n");
  }
  ```

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Passing to Functions

- In the Parameter List
  - For a single dimensional array – the size does not need to be indicated in the parameter list.
  - For a multi dimensional array – only the first dimension of size can be omitted in the parameter list.

- In the Argument List
  - For the argument when passing a whole array – no indices are given at all.
  - For the argument when passing a single element – all indices need to be indicated (in the correct range).

- Can not be used as the return type of a function.
In class Example

- Fill a SIZE x SIZE matrix
- Print a SIZE x SIZE matrix
- Multiply two SIZE x SIZE matrices
- In both orders to show that it isn’t commutative