EECS 10: Computational Methods in Electrical and Computer Engineering

Lecture 16

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Lecture 16: Overview

- Data Structures
  - Introduction
  - Arrays
    - Introduction
    - Indexing
    - Initialization
    - Multi-dimensional arrays
    - Operator associativity and precedence
  - Example 1
    - **`Histogram.c`**
  - Example 2
    - **`Dice2.c`**

Data Structures

- Introduction
  - Until now, we have used (mostly) single data elements of basic (non-composite) type
    - integral types
    - floating point types
  - Most programs, however, require complex *data structures* using composite types
    - arrays, lists, queues, stacks
    - trees, graphs
    - dictionaries
  - ANSI C provides built-in support for
    - arrays
    - structures, unions, enumerators
    - pointers

Arrays

- Array data type in C
  - Composite data type
    - Type is an array of a sub-type (e.g. array of `int`)
  - Fixed number of elements
    - Array size is fixed at time of definition (e.g. 100 elements)
  - Element access by index (aka. subscript)
    - Element-access operator: ***`array[index]`*** (e.g. `A[42]`)
- Example:

```
int A[10];   /* array of ten integers */

A[0] = 42;   /* access to elements */
A[1] = 100;
A[2] = A[0] + 5 * A[1];
```

Arrays

- Array Indexing
  - Start counting from 0
    - First element has index 0
    - Last element has index *Size*-1
- Example:

```
int A[10];

A[0] = 42;
A[1] = 100;
A[2] = A[0] + 5 * A[1];
A[3] = -1;
A[4] = 44;
A[5] = 55;
/* ... */
A[9] = 99;
```

	A
0	42
1	100
2	542
3	-1
4	44
5	55
6	0
7	0
8	0
9	99

Arrays

- Array Indexing
  - `for` loops are often very helpful
    - `for(i=0; i<N; i++) {...A[i]...}`
- Example:

```
int A[10];
int i;

for(i=0; i<10; i++)
   { A[i] = i*10 + i;
    }
for(i=0; i<10; i++)
   { printf("%d, ", A[i]);
    }
```

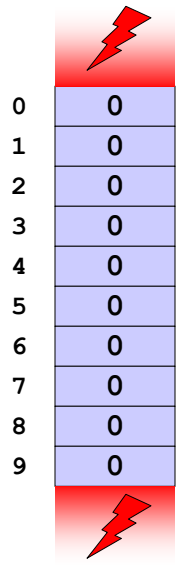
```
0, 11, 22, 33, 44, 55, 66, 77, 88, 99,
```

	A
0	0
1	11
2	22
3	33
4	44
5	55
6	66
7	77
8	88
9	99

Arrays

- Array Indexing
  - Array indices are *not* checked by the compiler, nor at runtime!
  - Accessing an array with an *index out of range* results in undefined behavior!
- Example:

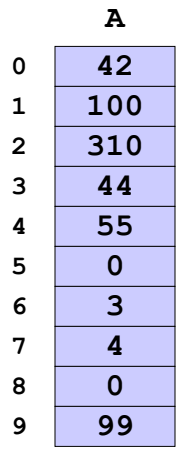
```
int A[10];
int i;

A[-1] = 42; /* INVALID ACCESS! */

for(i=0; i<=10; i++)
   /* INVALID LOOP RANGE! */
   { printf("%d, ", A[i]);
    }
```



Arrays

- Array Initialization
  - Static initialization at time of array definition
  - Initial elements listed in { }
- Example:

```
int A[10] = { 42, 100,
              310,  44,
               55,   0,
                3,   4,
                0,  99};
```



Arrays

- Array Initialization
  - Static initialization at time of array definition
  - Initial elements listed in { }
- Example:

```
int A[  ] = { 42, 100,
              310,  44,
               55,   0,
                3,   4,
                0,  99};
```

- With given initializer list, array size may be omitted
  - automatically determined

	A
0	42
1	100
2	310
3	44
4	55
5	0
6	3
7	4
8	0
9	99

Arrays

- Array Initialization
  - Static initialization at time of array definition
  - Initial elements listed in { }
- Example:

```
int A[10] = { 1, 2, 3};
```

- With given initializer list *and* array size, unlisted elements are zero-initialized
  - array is filled up with zeros

	A
0	1
1	2
2	3
3	0
4	0
5	0
6	0
7	0
8	0
9	0

Arrays

- Multi-dimensional Arrays
  - *Array of an array...*
- Example:

```
int M[3][2] = {{1, 2},
               {3, 4},
               {5, 6}};
int i, j;

for(i=0; i<3; i++)
   { for(j=0; j<2; j++)
        { printf("%d ",
                 M[i][j]);
         }
     printf("\n");
    }
```

M	0	1
0	1	2
1	3	4
2	5	6

```
1 2
3 4
5 6
```


Arrays

- Operator associativity and precedence

– parentheses, array access	`( )`, `[]`	left to right
– unary operators	`+`, `-`, `!`, `++`, `--`	right to left
– type casting	`(typename)`	right to left
– multiplication, division, modulo	`*`, `/`, `%`	left to right
– addition, subtraction	`+`, `-`	left to right
– shift left, shift right	`<<`, `>>`	left to right
– relational operators	`<`, `<=`, `>=`, `>`	left to right
– equality	`==`, `!=`	left to right
– logical and	`&&`	left to right
– logical or	`||`	left to right
– conditional operator	`?:`	left to right
– assignment operators	`=`, `+=`, `*=`, etc.	right to left
– comma operator	`,`	left to right

Arrays

- Program example: **`Histogram.c`**
  - Display a simple bar chart for 10 integer values
- Desired output:

```
% Histogram
Please enter data value  1: 111
Please enter data value  2: 222
Please enter data value  3: 33
Please enter data value  4: 333
[...]
Please enter data value 10: 111
 1:  111 **************
 2:  222 ***************************
 3:   33 ****
 4:  333 ******************************************
[...]
10:  111 **************
%
```


Arrays

- Program example: **`Histogram.c`** (part 1/3)

```
/* Histogram.c: print a histogram of data values        */
/* author: Rainer Doemer                                */
/* modifications:                                       */
/* 11/02/04 RD  initial version                         */

#include <stdio.h>

/* constants */

#define NUM_ROWS 10

/* main function */

int main(void)
{
   /* variable definitions */
   int Data[NUM_ROWS];
   int i, j, max;
   double scale;

...
```

Arrays

- Program example: **`Histogram.c`** (part 2/3)

```
...
   /* input section */
   for(i = 0; i < NUM_ROWS; i++)
      { printf("Please enter data value %2d: ", i+1);
        scanf("%d", &Data[i]);
       } /* rof */

   /* computation section */
   max = 0;
   for(i = 0; i < NUM_ROWS; i++)
      { if (Data[i] > max)
           { max = Data[i];
            } /* fi */
       } /* rof */
   scale = 70.0 / max;

...
```


Arrays

- Program example: **`Histogram.c`** (part 3/3)

```
...
/* output section */
   for(i = 0; i < NUM_ROWS; i++)
      { printf("%2d: %5d ", i+1, Data[i]);
        for(j = 0; j < Data[i]*scale; j++)
           { printf("*");
            } /* rof */
        printf("\n");
       } /* rof */

   /* exit */
   return 0;
} /* end of main */

/* EOF */
```

Arrays

- Example session: **`Histogram.c`**

```
% vi Histogram.c
% gcc Histogram.c -o Histogram -Wall -ansi
% Histogram
Please enter data value  1: 11
Please enter data value  2: 22
Please enter data value  3: 3
Please enter data value  4: 33
Please enter data value  5: 44
Please enter data value  6: 55
Please enter data value  7: 66
Please enter data value  8: 33
Please enter data value  9: 22
Please enter data value 10: 22
 1:    11 ***********
 2:    22 **********************
 3:     3 ****
 4:    33 *********************************
 5:    44 ********************************************
 6:    55 ***********************************************************
 7:    66 ****************************************************************
 8:    33 *********************************
 9:    22 **********************
10:    22 **********************
%
```


Arrays

- Earlier program example: **`Dice.c`** (part 1/4)

```
/* Dice.c: roll the dice                          */
/* author: Rainer Doemer                          */
/* modifications:                                 */
/* 10/28/04 RD  initial version                   */

#include <stdio.h>
#include <stdlib.h>
#include <time.h>

/* function definition */

int roll(void)
{
    int r;

    r = rand() % 6 + 1;
 /* printf("Rolled a %d.\n", r); */
    return r;
} /* end of roll */
...
```

Arrays

- Earlier program example: **`Dice.c`** (part 2/4)

```
...
/* main function */

int main(void)
{
    /* variable definitions */
    int i, n;
    int count1 = 0, count2 = 0, count3 = 0,
        count4 = 0, count5 = 0, count6 = 0;

    /* random number generator initialization */
    srand(time(0));

    /* input section */
    printf("Roll the dice: How many times? ");
    scanf("%d", &n);

...
```


Arrays

- Earlier program example: **`Dice.c`** (part 3/4)

```
... /* computation section */
    for(i = 0; i < n; i++)
       { switch(roll())
            { case 1:
                { count1++; break; }
              case 2:
                { count2++; break; }
              case 3:
                { count3++; break; }
              case 4:
                { count4++; break; }
              case 5:
                { count5++; break; }
              case 6:
                { count6++; break; }
              default:
                { printf("INVALID ROLL!");
                  exit(10); }
            } /* hctiws */
       } /* rof */
...
```

Arrays

- Earlier program example: **`Dice.c`** (part 4/4)

```
...

    /* output section */
    printf("Rolled a 1 %5d times.\n", count1);
    printf("Rolled a 2 %5d times.\n", count2);
    printf("Rolled a 3 %5d times.\n", count3);
    printf("Rolled a 4 %5d times.\n", count4);
    printf("Rolled a 5 %5d times.\n", count5);
    printf("Rolled a 6 %5d times.\n", count6);

    /* exit */
    return 0;
} /* end of main */

/* EOF */
```


Arrays

- Improved program example: **`Dice2.c`** (part 1/3)

```
/* Dice2.c: roll the dice                          */
/* author: Rainer Doemer                           */
/* modifications:                                  */
/* 11/04/04 RD  version using arrays               */
/* 10/28/04 RD  initial version                    */

#include <stdio.h>
#include <stdlib.h>
#include <time.h>

/* function definition */

int roll(void)
{
    int r;

    r = rand() % 6 + 1;
 /* printf("Rolled a %d.\n", r); */
    return r;
} /* end of roll */

...
```

Arrays

- Improved program example: **`Dice2.c`** (part 2/3)

```
...
/* main function */

int main(void)
{
    /* variable definitions */
    int i, n;
    int count[6] = { 0, 0, 0, 0, 0, 0 };

    /* random number generator initialization */
    srand(time(0));

    /* input section */
    printf("Roll the dice: How many times? ");
    scanf("%d", &n);

...
```


Arrays

- Improved program example: **`Dice2.c`** (part 3/3)

```
...
/* computation section */
    for(i = 0; i < n; i++)
       { count[roll()-1]++;
        } /* rof */

    /* output section */
    for(i = 0; i < 6; i++)
       { printf("Rolled a %d %5d times.\n",
                          i+1, count[i]);
        } /* rof */

    /* exit */
    return 0;
} /* end of main */

/* EOF */
```

Arrays

- Example session: **`Dice2.c`**

```
% vi Dice2.c
% gcc Dice2.c -o Dice2 -Wall -ansi
% Dice2
Roll the dice: How many times? 6000
Rolled a 1  1009 times.
Rolled a 2  1005 times.
Rolled a 3   962 times.
Rolled a 4   998 times.
Rolled a 5   996 times.
Rolled a 6  1030 times.
% Dice2
Roll the dice: How many times? 6000
Rolled a 1  1042 times.
Rolled a 2   983 times.
Rolled a 3   972 times.
Rolled a 4   979 times.
Rolled a 5  1022 times.
Rolled a 6  1002 times.
%
```