EECS 10: Computational Methods in Electrical and Computer Engineering

Lecture 23

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Lecture 23: Overview

- Pointers
  - Definition, initialization and assignment
  - Pointer dereferencing
  - Pointer arithmetic
    - Increment, decrement
  - Pointer comparison
  - String operations using pointers
    - Pointer and array type equivalence
    - Passing pointers to functions
    - Type qualifier **`const`**
  - Standard library functions
    - String operations defined in **`string.h`**

Pointers

- *Pointers* are variables whose values are *addresses*
  - The "address-of" operator (`&`) returns a pointer!
- Pointer Definition
  - The unary `*` operator indicates a pointer type in a definition

```
int x = 42;    /* regular integer variable */
int *p;        /* pointer to an integer */
```

- Pointer initialization or assignment
  - A pointer may be set to the "address-of" another variable

```
p = &x;        /* p points to x */
```

  - A pointer may be set to `0` (points to no object)

```
p = 0;         /* p points to no object */
```

  - A pointer may be set to `NULL` (points to "NULL" object)

```
#include <stdio.h>    /* defines NULL as 0 */
p = NULL;      /* p points to no object */
```

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Pointers

- Pointer Dereferencing
  - The unary `*` operator dereferences a pointer to the value it points to ("content-of" operator)

```
#include <stdio.h>

int  x = 42;    /* regular integer variable */
int *p = NULL;  /* pointer to an integer */
```

p	x
0	42

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Pointers

- Pointer Dereferencing
  - The unary `*` operator dereferences a pointer to the value it points to ("content-of" operator)

```
#include <stdio.h>

int  x = 42;   /* regular integer variable */
int *p = NULL; /* pointer to an integer */

p = &x;        /* make p point to x */
```

Pointers

- Pointer Dereferencing
  - The unary `*` operator dereferences a pointer to the value it points to ("content-of" operator)

```
#include <stdio.h>

int  x = 42;   /* regular integer variable */
int *p = NULL; /* pointer to an integer */

p = &x;        /* make p point to x */
printf("x is %d, content of p is %d\n", x, *p);
```

```
x is 42, content of p is 42
```

Pointers

- Pointer Dereferencing
  - The unary `*` operator dereferences a pointer to the value it points to ("content-of" operator)

```
#include <stdio.h>

int  x = 42;    /* regular integer variable */
int *p = NULL; /* pointer to an integer */

p = &x;         /* make p point to x */
printf("x is %d, content of p is %d\n", x, *p);
*p = 2 * *p;    /* multiply content of p by 2 */
printf("x is %d, content of p is %d\n", x, *p);
```

```
x is 42, content of p is 42
x is 84, content of p is 84
```

Pointers

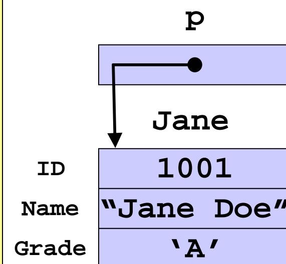
- Pointer Dereferencing
  - The `->` operator dereferences a pointer to a structure to the content of a structure member

```
struct Student
{  int  ID;
   char Name[40];
   char Grade;
};

struct Student Jane =
{1001, "Jane Doe", 'A'};

struct Student *p = &Jane;

void PrintStudent(void)
{
   printf("ID:    %d\n", p->ID);
   printf("Name:  %s\n", p->Name);
   printf("Grade: %c\n", p->Grade);
}
```




```
ID:    1001
Name:  Jane Doe
Grade: A
```

Pointers

- Pointer Arithmetic
  - Pointers pointing into arrays may be ...
    - ... incremented to point to the next array element
    - ... decremented to point to the previous array element

```
int x[5] = {10,20,30,40,50}; /* array of 5 integers */
int *p;                      /* pointer to integer */

p = &x[1];                   /* point p to x[1] */
printf("%d, ", *p);          /* print content of p */
```

```
20,
```


Pointers

- Pointer Arithmetic
  - Pointers pointing into arrays may be ...
    - ... incremented to point to the next array element
    - ... decremented to point to the previous array element

```
int x[5] = {10,20,30,40,50}; /* array of 5 integers */
int *p;                      /* pointer to integer */

p = &x[1];                   /* point p to x[1] */
printf("%d, ", *p);          /* print content of p */
p++;                         /* increment p by 1 */
printf("%d, ", *p);          /* print content of p */
```

```
20, 30,
```

Pointers

- Pointer Arithmetic
  - Pointers pointing into arrays may be ...
    - ... incremented to point to the next array element
    - ... decremented to point to the previous array element

```
int x[5] = {10,20,30,40,50}; /* array of 5 integers */
int *p;                      /* pointer to integer */

p = &x[1];                   /* point p to x[1] */
printf("%d, ", *p);          /* print content of p */
p++;                         /* increment p by 1 */
printf("%d, ", *p);          /* print content of p */
p--;                         /* decrement p by 1 */
printf("%d, ", *p);          /* print content of p */
```

```
20, 30, 20,
```


Pointers

- Pointer Arithmetic
  - Pointers pointing into arrays may be ...
    - ... incremented to point to the next array element
    - ... decremented to point to the previous array element

```
int x[5] = {10,20,30,40,50}; /* array of 5 integers */
int *p;                      /* pointer to integer */

p = &x[1];                   /* point p to x[1] */
printf("%d, ", *p);          /* print content of p */
p++;                         /* increment p by 1 */
printf("%d, ", *p);          /* print content of p */
p--;                         /* decrement p by 1 */
printf("%d, ", *p);          /* print content of p */
p += 2;                      /* increment p by 2 */
printf("%d, ", *p);          /* print content of p */
```

```
20, 30, 20, 40,
```

Pointers

- Pointer Comparison
  - Pointers may be compared for equality
    - operators `==` and `!=` are useful to determine *identity*
    - operators <, <=, >=, and > are *not* applicable

```
int x[5] = {10,20,10,20,10}; /* array of 5 integers */
int *p1, *p2;                /* pointers to integer */
p1 = &x[1]; p2 = &x[3];      /* point to x[1], x[3] */

if (p1 == p2)
  { printf("p1 and p2 are identical!\n");
  }
if (*p1 == *p2)
  { printf("Contents of p1 and p2 are same!\n");
  }
```

```
Contents of p1 and p2 are same!
```


Pointers

- Pointer Comparison
  - Pointers may be compared for equality
    - operators `==` and `!=` are useful to determine *identity*
    - operators <, <=, >=, and > are *not* applicable

```
int x[5] = {10,20,10,20,10}; /* array of 5 integers */
int *p1, *p2;                /* pointers to integer */
p1 = &x[1]; p2 = &x[3];      /* point to x[1], x[3] */
p1 += 2;                     /* increment p1 by 2 */
if (p1 == p2)
  { printf("p1 and p2 are identical!\n");
  }
if (*p1 == *p2)
  { printf("Contents of p1 and p2 are same!\n");
  }
```

```
p1 and p2 are identical!
Contents of p1 and p2 are same!
```

Pointers

- String Operations using Pointers
  - Example: String length

```
int Length(char *s)
{
   int l = 0;
   char *p = s;

   while(*p != 0)
   { p++;
     l++;
   }
   return l;
}
```

```
char s1[] = "ABC";
char s2[] = "Hello World!";

printf("Length of %s is %d\n",
            s1, Length(&s1[0]));
printf("Length of %s is %d\n",
            s2, Length(&s2[0]));
```

```
Length of ABC is 3
Length of Hello World! is 12
```

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Pointers

- String Operations using Pointers
  - Example: String length

```
int Length(char *s)
{
   int l = 0;
   char *p = s;

   while(*p != 0)
   { p++;
     l++;
   }
   return l;
}
```

```
char s1[] = "ABC";
char s2[] = "Hello World!";

printf("Length of %s is %d\n",
            s1, Length(&s1[0]));
printf("Length of %s is %d\n",
            s2, Length(s2));
```

```
Length of ABC is 3
Length of Hello World! is 12
```

  - Array and pointer types are equivalent
    - `s2` is an array, but can be passed as a pointer argument
    - Character array `s2` is same as character pointer `&s2[0]`

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Pointers

- String Operations using Pointers
  - Example: String length

```
int Length(char *s)
{
   int l = 0;
   char *p = s;

   while(*p != 0)
   { p++;
     l++;
   }
   return l;
}
```

```
char s1[] = "ABC";
char *s2  = "Hello World!";

printf("Length of %s is %d\n",
            s1, Length(s1));
printf("Length of %s is %d\n",
            s2, Length(s2));
```

```
Length of ABC is 3
Length of Hello World! is 12
```

  - Array and pointer types are equivalent
    - **s1** is an array of characters, **s2** is a pointer to character
    - Both **s1** and **s2** can be passed to character pointer **s**

Pointers

- String Operations using Pointers
  - Example: String length

```
int Length(char s[])
{
   int l = 0;
   char *p = s;

   while(*p != 0)
   { p++;
     l++;
   }
   return l;
}
```

```
char s1[] = "ABC";
char *s2  = "Hello World!";

printf("Length of %s is %d\n",
            s1, Length(s1));
printf("Length of %s is %d\n",
            s2, Length(s2));
```

```
Length of ABC is 3
Length of Hello World! is 12
```

  - Array and pointer types are equivalent
    - **s1** is an array of characters, **s2** is a pointer to character
    - Both **s1** and **s2** can be passed to character array **s**

Pointers

- String Operations using Pointers
  - Example: String copy

```
void Copy(
      char *Dst,
      char *Src)
{
 do{
      *Dst = *Src;
      Dst++;
    } while(*Src++);
}
```

```
char s1[] = "ABC";
char s2[] = "Hello World!";

printf("s1 is %s, s2 is %s\n",
               s1, s2);
```

```
s1 is ABC, s2 is Hello World!
```


Pointers

- String Operations using Pointers
  - Example: String copy

```
void Copy(
      char *Dst,
      char *Src)
{
 do{
      *Dst = *Src;
      Dst++;
    } while(*Src++);
}
```

```
char s1[] = "ABC";
char s2[] = "Hello World!";

printf("s1 is %s, s2 is %s\n",
               s1, s2);
Copy(s2, s1);
printf("s1 is %s, s2 is %s\n",
               s1, s2);
```

```
s1 is ABC, s2 is Hello World!
s1 is ABC, s2 is ABC
```

Pointers

- String Operations using Pointers
  - Example: String copy

```
void Copy(
     char *Dst,
     char *Src)
{
 do{
     *Dst = *Src;
     Dst++;
   } while(*Src++);
}
```

```
char s1[] = "ABC";
char s2[] = "Hello World!";

printf("s1 is %s, s2 is %s\n",
               s1, s2);
Copy(s2, s1);
printf("s1 is %s, s2 is %s\n",
               s1, s2);
```

```
s1 is ABC, s2 is Hello World!
s1 is ABC, s2 is ABC
```

  - Passing pointers as arguments to functions
    - Function can modify caller data by pointer dereferencing
    - Passing pointers = Pass by reference!

Pointers

- String Operations using Pointers
  - Example: String copy

```
void Copy(
     char *Dst,
    const char *Src)
{
 do{
     *Dst = *Src;
     Dst++;
   } while(*Src++);
}
```


```
char s1[] = "ABC";
char s2[] = "Hello World!";

printf("s1 is %s, s2 is %s\n",
               s1, s2);
Copy(s2, s1);
printf("s1 is %s, s2 is %s\n",
               s1, s2);
```

```
s1 is ABC, s2 is Hello World!
s1 is ABC, s2 is ABC
```

  - Passing pointers as arguments to functions
    - Function can modify caller data by pointer dereferencing
    - Type qualifier **`const`**:
      Modification by pointer derefencing *not* allowed!

Pointers

- String Operations using Pointers
  - Example: String copy

```
void Copy(
    const char *Dst,
    const char *Src)
{
 do{
     *Dst = *Src;
     Dst++;
   } while(*Src++);
```

Error!
Write access to `const` data!

```
char s1[] = "ABC";
char s2[] = "Hello World!";

printf("s1 is %s, s2 is %s\n",
               s1, s2);
Copy(s2, s1);
printf("s1 is %s, s2 is %s\n",
               s1, s2);
```

```
s1 is ABC, s2 is Hello World!
s1 is ABC, s2 is ABC
```

  - Passing pointers as arguments to functions
    - Function can modify caller data by pointer dereferencing
    - Type qualifier `const`:
      Modification by pointer derefencing *not* allowed!

Standard Library Functions

- Functions declared in `string.h` (part 1/2)
  - `typedef unsigned int size_t;`
    - type definition for length of strings
  - `size_t strlen(const char *s);`
    - returns the length of string `s`
  - `int strcmp(const char *s1, const char *s2);`
    - alphabetically compares string `s1` with string `s2`
    - returns -1 / 0 / 1 for less-than / equal-to / greater-than
  - `int strncmp(const char *s1, const char *s2, size_t n);`
    - same as previous, but compares maximal `n` characters
  - `int strcasecmp(const char *s1, const char *s2);`
  - `int strncasecmp(const char *s1, const char *s2, size_t n);`
    - same as string comparisons above, but case-insensitive

Standard Library Functions

- Functions declared in `string.h` (part 2/2)
  - `char *strcpy(char *s1, const char *s2);`
    - copies string `s2` into string `s1`
  - `char *strncpy(char *s1, const char *s2, size_t n);`
    - copies maximal `n` characters of string `s2` into string `s1`
  - `char *strcat(char *s1, const char *s2);`
    - concatenates string `s2` to string `s1`
  - `char *strncat(char *s1, const char *s2, size_t n);`
    - concatenates maximal `n` characters of string `s2` to string `s1`
  - `char *strchr(const char *s, int c);`
    - returns a pointer to the first character `c` in string `s`, or `NULL` if not found
  - `char *strrchr(const char *s, int c);`
    - returns a pointer to the last character `c` in string `s`, or `NULL` if not found
  - `char *strstr(const char *s1, const char *s2);`
    - returns a pointer to the first appearance of `s2` in string `s1` (or `NULL`)

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