

EECS 22: Advanced C Programming

Lecture 18

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Lecture 18: Overview

- **Pointer Operations**
 - Definition, initialization and assignment
 - Pointer dereferencing
 - Pointer arithmetic
 - Increment, decrement
 - Pointer comparison
- **Pointers and Arrays**
 - Equivalence!
 - Array layout in linear address space

Pointer Operations

- *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
 - A pointer may be set to 0 (points to no object)
 - A pointer may be set to **NULL** (points to “NULL” object)

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

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

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

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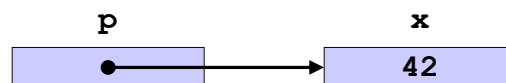
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Pointer Operations

- 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
```



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Pointer Operations

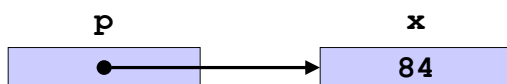
- Pointer Dereferencing
 - The unary `*` operator dereferences a pointer to the value it points to ("*content-of*" operator)

```
#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
```



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Pointer Operations

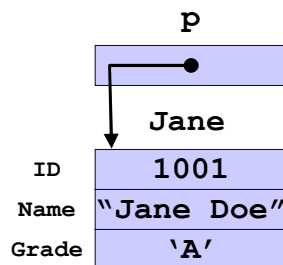
- Pointer Dereferencing
 - The `->` operator dereferences a pointer to a structure to the named structure member ("*member-access*" operator)

```
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
```

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Pointer Operations

- Pointer Arithmetic

- Pointers pointing into arrays may be ...
 - ... incremented to point to the next array element
 - ... decremented to point to the previous array element
 - Boundaries apply! Pointing outside of `A[0]` to `A[N]` is undefined!

```
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,

Pointer Operations

- Pointer Arithmetic

- Pointers pointing into arrays may be ...
 - ... incremented to point to the next array element
 - ... decremented to point to the previous array element
 - Boundaries apply! Pointing outside of `A[0]` to `A[N]` is undefined!

```
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,

Pointer Operations

- Pointer Arithmetic

- Pointers pointing into arrays may be ...
 - ... incremented to point to the next array element
 - ... decremented to point to the previous array element
 - Boundaries apply! Pointing outside of `A[0]` to `A[N]` is undefined!

```
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,
```

Pointer Operations

- Pointer Arithmetic

- Pointers pointing into arrays may be ...
 - ... incremented to point to the next array element
 - ... decremented to point to the previous array element
 - Boundaries apply! Pointing outside of `A[0]` to `A[N]` is undefined!

```
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,
```

Pointer Operations

- Pointer Comparison

- Pointers may be compared for object identification or position
 - operators == and != are useful to determine *object identity*
 - operators <, <=, >=, and > are applicable
only to objects in the same array

```
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 the same!\n");
  }
```

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

Pointer Operations

- Pointer Comparison

- Pointers may be compared for object identification or position
 - operators == and != are useful to determine *object identity*
 - operators <, <=, >=, and > are applicable
only to objects in the same array

```
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 the same!\n");
  }
```

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

Pointer Operations

- Pointer Comparison
 - Pointers may be compared for object identification or position
 - operators == and != are useful to determine object *identity*
 - operators <, <=, >=, and > are applicable *only* to objects in the *same array*

```
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 points to an element after p2!\n");
  }
if (p1 < p2)
  { printf("p1 points to an element before p2!\n");
  }
```

```
p1 points to an element before p2!
```

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Pointers and Arrays

- In C, *Pointers and Arrays are equivalent!*
 - A pointer represents an address in memory
 - An array is represented by the address of its first element in memory
- Passing Arrays and Pointers to Functions
 - Arrays are passed *by reference*
 - Pointers *are references* and passed as such
- Array Access is equivalent to Pointer Dereferencing
 - Example:

```
int A[10];
...
A[0] = 42;
...
A[5] = 17;
```

```
int A[10], *p = &A[0];
...
*p = 42;
...
*(p+5) = 17;
```

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Pointers and Arrays

- Dynamic Arrays

- Example 1:

- Fixed 1-dim. array

- Fixed definition
- Passed as fixed array
- Fixed array access
- Fixed size everywhere!

```
int Sum(int A[100])
{
    int i, sum = 0;
    for(i=0; i<100; i++)
    { sum += A[i];
    }
    return sum;
}

int main(void)
{
    int d[100], s;
    ...
    s = Sum(d);
    ...
    return 0;
}
```

Pointers and Arrays

- Dynamic Arrays

- Example 2:

- Fixed 1-dim. array

- Fixed definition
- Passed as fixed array
plus size
- Received as pointer
and size!
- Accessed via pointer
with offset!

```
int Sum(int *p, int m)
{
    int i, sum = 0;
    for(i=0; i<m; i++)
    { sum += *(p + i);
    }
    return sum;
}

int main(void)
{
    int d[100], s;
    ...
    s = Sum(d, 100);
    ...
    return 0;
}
```


Pointers and Arrays

- Dynamic Arrays
 - Example 3:
 - Dynamic 1-dim. array
 - Dynamic allocation
 - Passed as pointer plus size
 - Received as pointer and size!
 - Accessed via pointer with offset!

```
int Sum(int *p, int m)
{
    int i, sum = 0;
    for(i=0; i<m; i++)
    { sum += *(p + i);
    }
    return sum;
}

int main(void)
{
    int *d, s;
    d = malloc(sizeof(int)*100);
    if (!d)
        { exit(10); }
    ...
    s = Sum(d, 100);
    free(d);
    ...
    return 0;
}
```

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Pointers and Arrays

- Dynamic Arrays
 - Example 4:
 - Fixed 2-dim. array
 - Fixed definition
 - Passed as fixed array
 - Fixed array access
 - Fixed sizes everywhere!

```
int Sum(int A[5][20])
{
    int i, j, sum = 0;
    for(i=0; i<5; i++)
        for(j=0; j<20; j++)
            { sum += A[i][j];
            }
    return sum;
}

int main(void)
{
    int d[5][20], s;
    ...
    s = Sum(d);
    ...
    return 0;
}
```

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Pointers and Arrays

- Dynamic Arrays
 - Example 5:
 - Mixed 2-dim. array**
 - Fixed definition of dimension 1 (columns)
 - Dynamic allocation of dimension 2 (rows)
 - Passed as array with dynamic dimension 2 (number of rows) and sizes
 - Fixed array access
 - Multi-dimensional arrays are arrays of arrays...

```
int Sum(int A[][20], int m, int n)
{
    int i, j, sum = 0;
    for(i=0; i<m; i++)
        for(j=0; j<n; j++)
            { sum += A[i][j];
            }
    return sum;
}

int main(void)
{
    int (*d)[20], s;
    d = malloc(sizeof(int[20])*5);
    if (!d)
        { exit(10); }
    ...
    s = Sum(d, 5, 20);
    free(d);
    ...
    return 0;
}
```

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Pointers and Arrays

- Dynamic Arrays
 - Example 6:
 - Dynamic 2-dim. array**
 - Dynamic allocation of all dimensions
 - Passed as pointer
 - Received as pointer!
 - Accessed via pointer!
 - An array...
 - of any dimension
 - of any size
 - ...can be mapped into linear address space!

```
int Sum(int *p, int m, int n)
{
    int i, j, sum = 0;
    for(i=0; i<m; i++)
        for(j=0; j<n; j++)
            { sum += *(p + i*n + j);
            }
    return sum;
}

int main(void)
{
    int *d, s;
    d = malloc(sizeof(int)*5*20);
    if (!d)
        { exit(10); }
    ...
    s = Sum(d, 5, 20);
    free(d);
    ...
    return 0;
}
```

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