Introduction to Computers and Programming

Lecture 5 – Program scope and basic pointer

Chap 10 & 11

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Program organization

Local Variables

- A variable declared in the body of a function is said to be ***local*** to the function:

```
int sum_digits(int n)
{
  int sum = 0;    /* local variable */

  while (n > 0) {
    sum += n % 10;
    n /= 10;
  }

  return sum;
}
```

Local Variables

- Default properties of local variables:
  - ***Automatic storage duration.*** Storage is “automatically” allocated when the enclosing function is called and deallocated when the function returns.
  - ***Block scope.*** A local variable is visible from its point of declaration to the end of the enclosing function body.

- In C99, it’s possible for a local variable to have a very small scope:

```
void f(void)
{
  …
  int i;
  …
}
```

scope of i

Parameters

- Parameters have the same properties as local variables

  automatic storage duration and block scope

- Each parameter is initialized automatically when a function is called (by being assigned the value of the corresponding argument).

```
void store_zeros(int a[], int n)
{
  int i;

  for (i = 0; i < n; i++)
    a[i] = 0;
}
```

```
store_zeros(b, 100);
```

External / Global Variables

- Passing arguments is one way to transmit information to a function.
- Functions can also communicate through ***external variables*** (also known as ***global variables***)—variables that are declared outside the body of any function.

```
/* external variables */
int contents[100];
int top = 0;

void make_empty(void)
{
  top = 0;
}

bool is_empty(void)
{
  return top == 0;
}
```

```
void push(int i)
{
  if (is_full()
    stack_overflow();
  else
    contents[top++] = i;
}

int pop(void)
{
  if (is_empty())
    stack_underflow();
  else
    return contents[--top];
}
```

External Variables

- Properties of external variables:
  - Static storage duration
  - File scope
- Having ***file scope*** means that an external variable is visible from its point of declaration to the end of the enclosing file.

File1.c

```
int x;
```

File2.c

```
int y;
extern int x;
```

Static Local Variables

- Including `static` causes a local variable to have ***static storage duration.***
- A variable with static storage duration has a permanent storage location, so it retains its value throughout the execution of the program.
- Example:

```
void f(void)
{
  static int i;    /* static local variable */
  …
}
```

- A static local variable still has block scope, so it’s not visible to other functions.

Pros and Cons of External Variables

- External variables are convenient:
  - when many functions must share a variable
  - when a few functions share a large number of variables.
- it’s better for functions to communicate through parameters rather than by sharing variables:
  - If we change an external variable, we’ll need to check every function to see how the change affects it.
  - If an external variable is assigned an incorrect value, it may be difficult to identify the guilty function.
  - Functions that rely on external variables are hard to reuse in other programs.
- Don’t use the same external variable for different purposes in different functions.

Pros and Cons of External Variables

- Making variables external when they should be local can lead to some rather frustrating bugs.
- Code that is supposed to display a 10 × 10 arrangement of asterisks:

```
int i;

void print_one_row(void)
{
  for (i = 1; i <= 10; i++)
    printf("*");
}

void print_all_rows(void)
{
  for (i = 1; i <= 10; i++) {
    print_one_row();
    printf("\n");
  }
}
```

- Instead of printing 10 rows, `print_all_rows` prints only one.

Blocks

- compound statements of the form

  { *statements* }

- C allows compound statements to contain declarations as well as statements:

  { *declarations* *statements* }

- This kind of compound statement is called a ***block.***

```
if (i > j) {
  /* swap values of i and j */
  int temp = i;
  i = j;
  j = temp;
}
```

Blocks

- The storage of a variable declared in a block is automatic:
  - storage for the variable is allocated when the block is entered and deallocated when the block is exited.
- The variable has block scope; it can't be referenced outside the block.
- A variable that belongs to a block can be declared `static` to give it static storage duration.

Blocks

- The body of a function is a block.
- Blocks are also useful inside a function body when we need variables for temporary use.
- Advantages of declaring temporary variables in blocks:
  - Avoids cluttering declarations at the beginning of the function body with variables that are used only briefly.
  - Reduces name conflicts.
- C99 allows variables to be declared anywhere within a block.

Scope

- Scope rules:
  - to determine a variable where is relevant at a given point in the program.
- The most important scope rule:
  - When a declaration inside a block names an identifier that's already visible
  - a new declaration temporarily "hides" the old one, and the identifier takes on a new meaning.
- At the end of the block, the identifier regains its old meaning.

i is a variable with static storage duration and file scope

```
int i ;              /* Declaration 1 */

void f(int i )       /* Declaration 2 */
{
  i = 1;
}

void g(void)
{
  int i = 2;         /* Declaration 3 */

  if (i > 0) {
    int i ;          /* Declaration 4 */

    i = 3;
  }

  i = 4;
}

void h(void)
{
  i = 5;
}
```

i is a parameter with block scope.

i is an automatic variable with block scope.

i is also automatic and has block scope.

Organizing a C Program

- There are several ways to organize a program so that these rules are obeyed.
- One possible ordering:
  - `#include` directives
  - `#define` directives
  - Type definitions
  - Declarations of external variables
  - Prototypes for functions other than `main`
  - Definition of `main`
  - Definitions of other functions

Write comments for functions

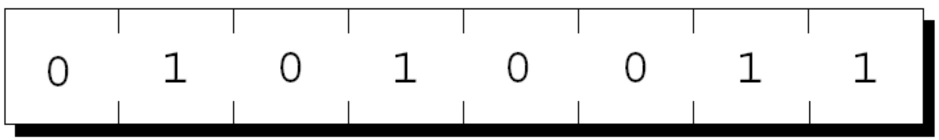
- It's a good idea to have a boxed comment preceding each function definition.
- Information to include in the comment:
  - Name of the function
  - Purpose of the function
  - Meaning of each parameter
  - Description of return value (if any)
  - Description of side effects (such as modifying external variables)

```
//
// this is to comment a function
//
void func(int A, int B) {
      //C = A*B;     /* this is another
      comment line after C statement */
}
```

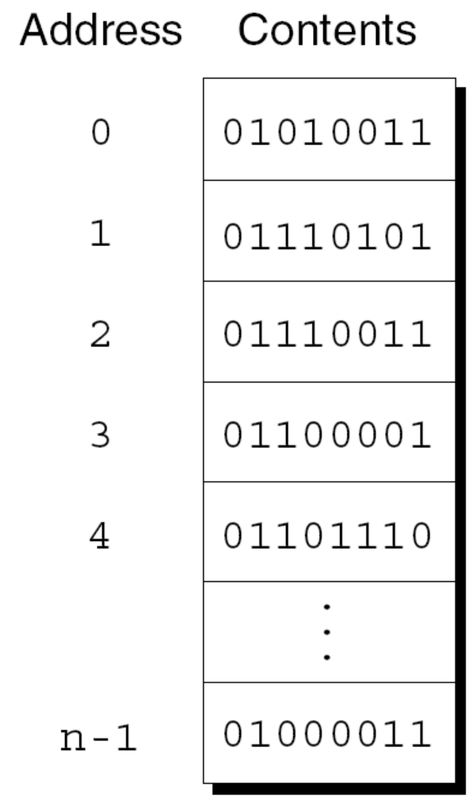
Basic pointer

Pointer Variables

- In most modern computers, main memory is divided into ***bytes,*** with each byte capable of storing eight bits of information:

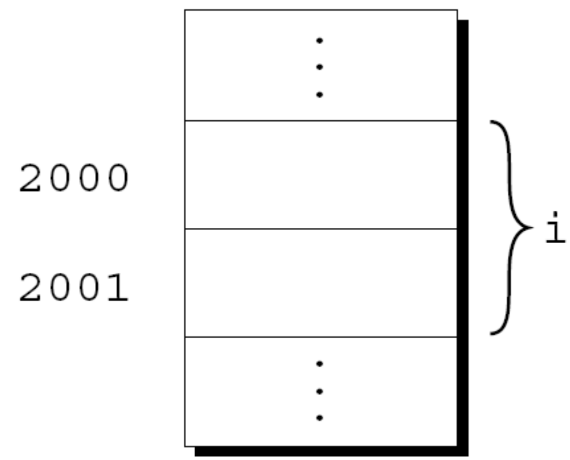


- Each byte has a unique ***address.***
- If there are *n* bytes in memory, we can think of addresses as numbers that range from 0 to *n* – 1:



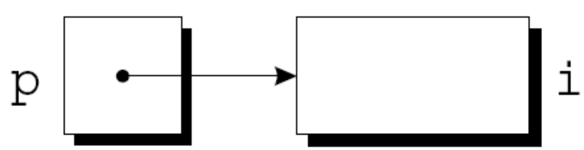
Pointer Variables

- The address of the first byte is said to be the address of the variable.
- The address of the variable `short int i` is 2000:



- Addresses can be stored in special ***pointer variables.***
- When we store the address of a variable `i` in the pointer variable `p`:

  `p` "points to" `i`.



Declaring Pointer Variables

- When a pointer variable is declared, its name must be preceded by an asterisk:

```
int *p;
```

- `p` is a pointer variable capable of pointing to ***objects*** of type `int`.
- Pointer variables can appear in declarations along with other variables:

```
int i, j, a[10], b[20], *p, *q;
```

- C requires that every pointer variable point only to objects of a particular type (the ***referenced type***):

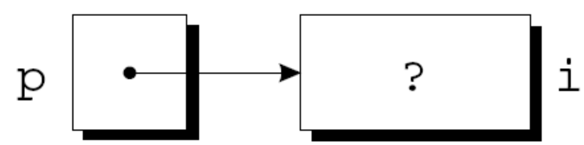
```
int *p;      /* points only to integers   */
double *q;   /* points only to doubles    */
char *r;     /* points only to characters */
```

The Address Operator

- C provides a pair of operators for pointers.
  - Use the `&` (address) operator to get the address
  - Use the `*` (***indirection***) operator to gain access to the object.

- Initialize: Assign the address of a variable to a pointer variable

```
int i, *p;
…
p = &i;
```



The Address Operator

- It's also possible to initialize a pointer variable at the time it's declared:

```
int i;

int *p = &i;
```

- The declaration of `i` can even be combined with the declaration of `p`:

```
int i, *p = &i;
```

The Indirection Operator

- If `p` points to `i`, we can print the value of `i` as follows:

```
printf("%d\n", *p);
```

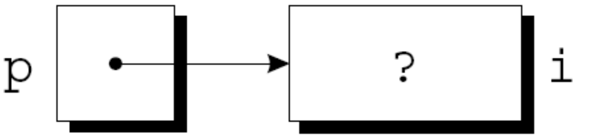
- Applying `&` to a variable produces a pointer to the variable. Applying `*` to the pointer takes us back to the original variable:

```
j = *&i;    /* same as j = i; */
```

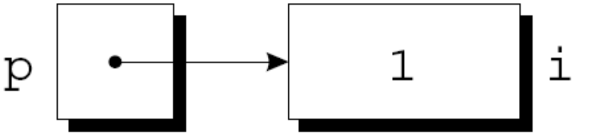
- When `p` points to `i`, `*p` is an ***alias*** for `i`.
  - `*p` has the same value as `i`.
  - Changing the value of `*p` changes the value of `i`.

The Indirection Operator

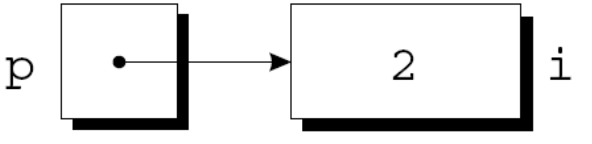
```
p = &i;
```




```
i = 1;
```




```
printf("%d\n", i);     /* prints 1 */
printf("%d\n", *p);    /* prints 1 */
*p = 2;
```




```
printf("%d\n", i);     /* prints 2 */
printf("%d\n", *p);    /* prints 2 */
```

The Indirection Operator

- Applying the indirection operator to an uninitialized pointer variable causes undefined behavior:

```
int *p;
printf("%d", *p);    /*** WRONG ***/
```

- Assigning a value to `*p` is particularly dangerous:

```
int *p;
*p = 1;    /*** WRONG ***/
```

Pointer Assignment

- Assume that the following declaration is in effect:

```
int i, j, *p, *q;
```

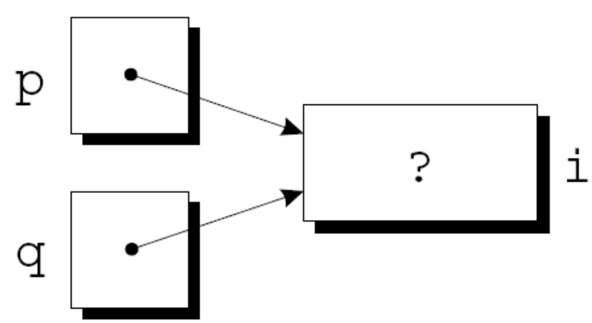
- Example of pointer assignment:

```
p = &i;
```

- Another example of pointer assignment:

```
q = p;
```

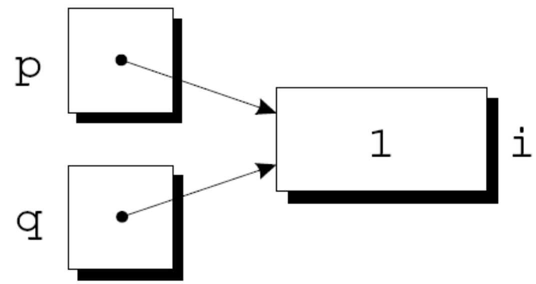
`q` now points to the same place as `p`:



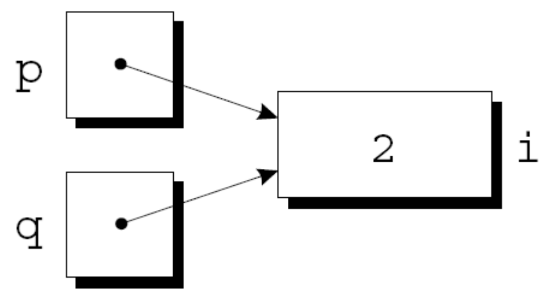
Pointer Assignment

- If `p` and `q` both point to `i`, we can change `i` by assigning a new value to either `*p` or `*q`:

```
*p = 1;
```



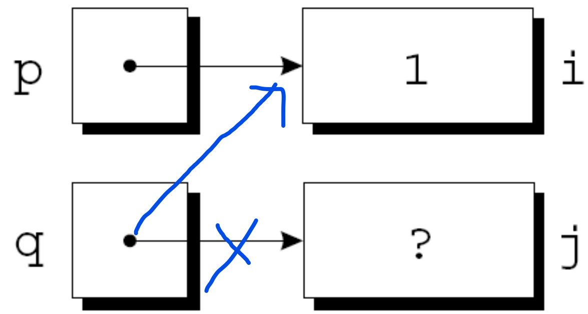

```
*q = 2;
```



- Any number of pointer variables may point to the same object.

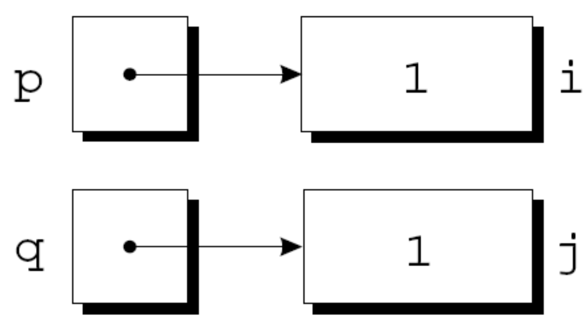
Pointer Assignment

```
p = &i;
q = &j;
i = 1;
```



1. **`q = p;`** **pointer assignment**

2. `*q = *p;`



Pointers as Arguments

- New definition of `decompose`:

```
void decompose(double x, long *int_part,
               double *frac_part)
{
  *int_part = (long) x;
  *frac_part = x - *int_part;
}
```

- Possible prototypes for `decompose`:

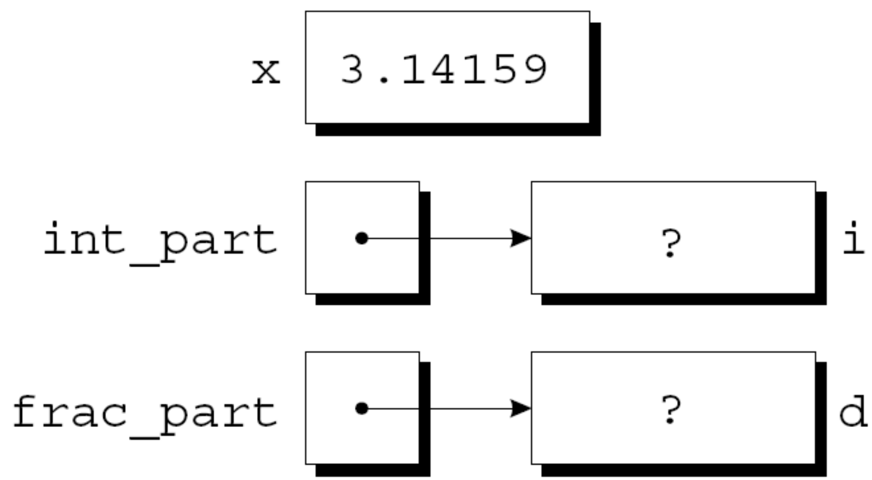
```
void decompose(double x, long *int_part,
               double *frac_part);

void decompose(double, long *, double *);
```

Pointers as Arguments

- A call of `decompose`:

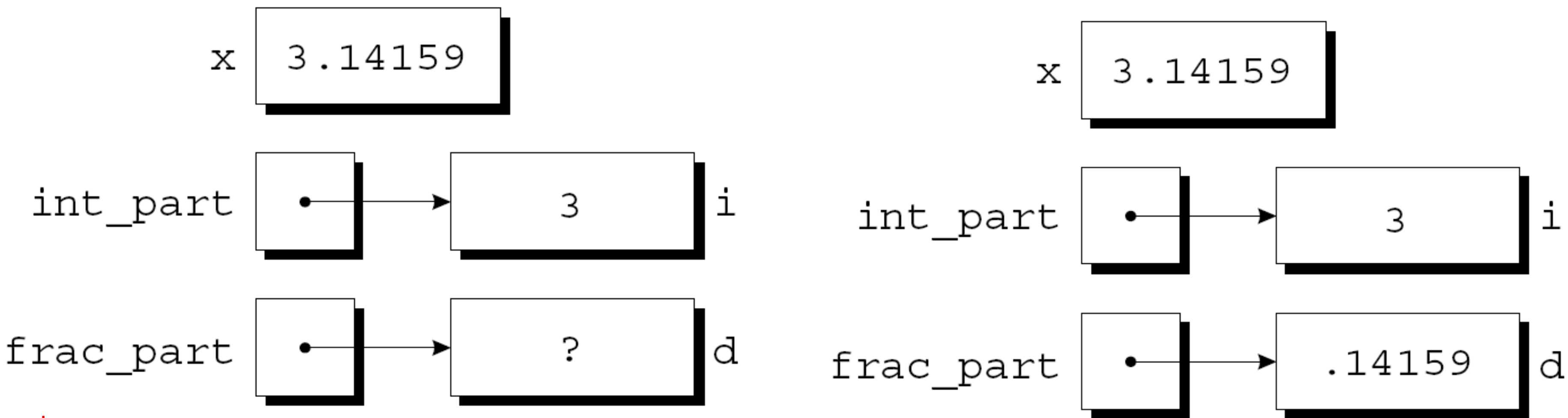
  ```
  decompose(3.14159, &i, &d);
  ```

- As a result of the call, `int_part` points to `i` and `frac_part` points to `d`:



Pointers as Arguments

```
*int_part = (long) x;
*frac_part = x - *int_part;
```



Pointers as Arguments

- Arguments in calls of `scanf` are pointers:

```
int i;
…
scanf("%d", &i);
```

Without the `&`, `scanf` would be supplied with the *value* of `i`.

Failing to pass pointers may go undetected.

Pointers as Arguments

- Although `scanf`'s arguments must be pointers, it's not always true that every argument needs the `&` operator:

```
int i, *p;
…
p = &i;
scanf("%d", p);
```

- Using the `&` operator in the call would be wrong:

```
scanf("%d", &p);    /*** WRONG ***/
```

Pointers as Arguments

- Failing to pass a pointer to a function when one is expected can have disastrous results.
- A call of `decompose` in which the `&` operator is missing:

```
decompose(3.14159, i, d);
```

- When `decompose` stores values in `*int_part` and `*frac_part`, it will attempt to change unknown memory locations instead of modifying `i` and `d`.
- If we've provided a prototype for `decompose`, the compiler will detect the error.

Using `const` to Protect Arguments

- When an argument is a pointer to a variable `x`, we normally assume that `x` will be modified:

```
f(&x);
```

- We can use `const` to document that a function won't change an object.
- `const` goes in the parameter's declaration, just before the specification of its type:

```
void f(const int *p)
{
  *p = 0;    /*** WRONG ***/
}
```

Attempting to modify `*p` is an error that the compiler will detect.

Pointers as Return Values

- Functions are allowed to return pointers:

```
int *max(int *a, int *b)
{
  if (*a > *b)
    return a;
  else
    return b;
}
```

- A call of the `max` function:

```
int *p, i, j;
…
p = max(&i, &j);
```

After the call, `p` points to either `i` or `j`.

Pointers as Return Values

- A function could also return a pointer to an external variable or to a static local variable.
- Never return a pointer to an *automatic* local variable:

```
int *f(void)
{
  int i;
  …
  return &i;
}
```

The variable `i` won't exist after `f` returns.

Pointers as Return Values

- Pointers can point to array elements.
- `a` is an array: `&a[i]` is a pointer to element `i` of `a`.

- A function that returns a pointer to the middle element of `a`, assuming that `a` has `n` elements:

```
int *find_middle(int a[], int n) {
  return &a[n/2];
}
```

Memory segment in Linux system

1. Text segment (i.e. instructions)
2. Initialized data segment
3. Uninitialized data segment (bss)
4. Heap
5. Stack