Introduction to Scientific Programming

The C Language

More Pointers

Arrays

- An array in C is a group of elements of the same type.
- Arrays use square brackets like so:

```
int some_nums[200];
char bunch_o_chars[45];

some_nums[3]= 5;
bunch_o_chars[0]= 'a';
```

In C, we must give the length when we declare the array. *one caveat which we will see later*

Arrays

Passing arrays into functions

- We prototype a function which accepts an array like this:

```
void process_array (int []);
int calc_array (char[]);
```

- And write the function like this:

```
void process_array (int all_nums[])
{
    all_nums[1]= 3;

}
```

- And call the function like this:

```
int some_numbers [100];
process_array(some_numbers);
```

Pointers

Pass by value/reference

- Normally when passing a variable to a function, the compiler makes a **COPY** of the variable in the function.
- Hence changing the value of the argument in the function does not change the original value.
- This is called pass by value.
- Sometimes, like in scanf(), we want to change the variable inside the function.
- To do this, we pass a pointer as input argument to the function
- This is called **pass by reference.**

Pointers

Function argument passing by reference

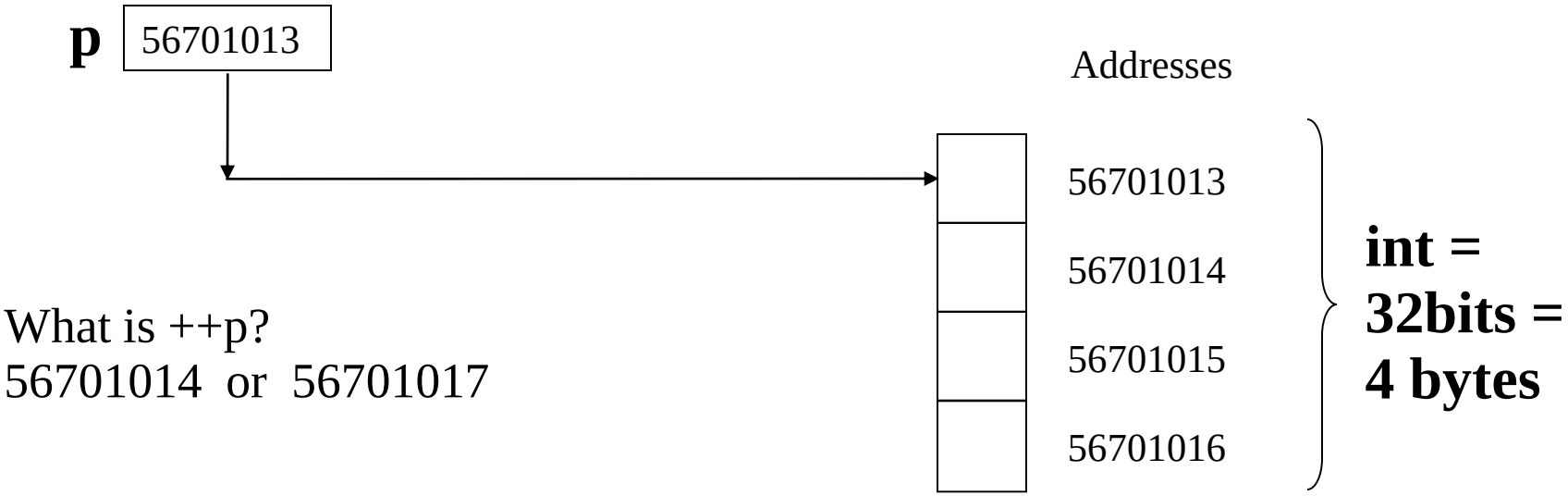
- If we pass a pointer to a variable into a function we can change the value of the variable within the function.
- This is what is going on when we use & in scanf.

Pointers

What are pointers?

- Pointers "point at" areas in your computer's memory.

```
int *p; /* p is a pointer to an int */
```



Pointers

What are pointers?

- Pointers "point at" areas in your computer's memory.

```
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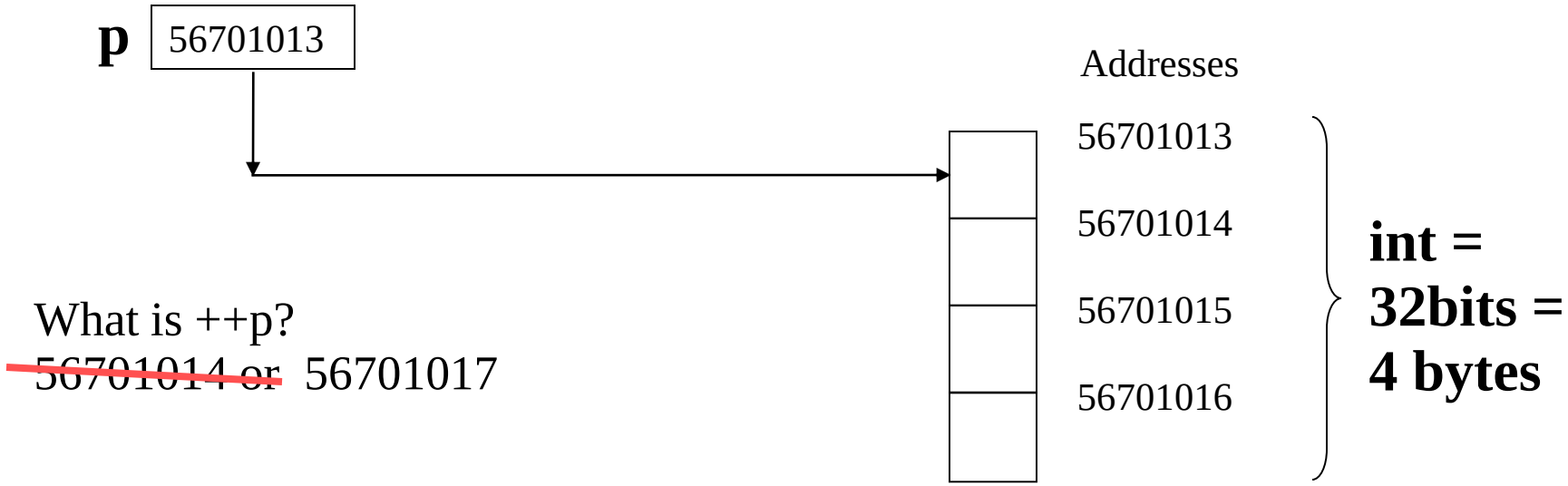


Pointers

Pointer Access

- * on a pointer means “value of”
- & on any variable means “address of”

```
int *p;
int q = 5;
p = &q;

*p = 10;
```

p is a pointer to an int
q has an int value of “5”
p is assigned the address of q
Therefore *p has the value of “10”
q now has the value of “10“

*see p1.c

Pointers

Common C mistakes

- Remember to assign a valid memory space to the pointer before using it.

```
int *p;

*p = 5;
```

This will cause problems, we are potentially writing to some invalid Address in memory.

Pointers

Allocating memory

- We can allocate memory with the **`malloc`** function:

```
p = (int *)malloc(sizeof(int));
```

Cast to appropriate type

sizeof(int) returns how Many bytes an int type requires

```
*p = 5;
```

Pointers and NULL

- NULL pointer is a reserved value representing no object.
- In many implementations it is the value “0”, but it is not necessary to be so.
- Good practice to initialize pointers to NULL.

```
int *p = NULL;

if (p == NULL) {
   fprintf(stderr, “p points to no object\n”);
}
```

Pointers and Memory

- Declare a pointer with an *
- Use an & to get the "address of" (and convert a variable to a pointer)
- Use an * to get the value "pointed at"

```
int *p;
int q = 5;

p = &q;
*p = 6;
```

Pointer to integer

q assigned with value 5

Variable p points to q's memory

q now has value 6

Pointer and Arrays

- In C, pointers are often used to manipulate arrays

```
//p2_arrays.c
int *p;
int q[7];

p = &q[0];
*p = 3;

p++;
*p++ = 4;
*p++ = 5;

printf("q[0] %d, q[1] %d, q[2] %d\n",q[0],q[1],q[2]);
```

Array of 7 integers

p points to memory location of q[0]

q[0] == 3

q[1] == 4

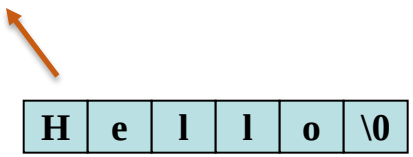
Pointers and char arrays

- A pointer to a char array is common way to refer to a string:

```
char *string = NULL;

string = (char *)malloc((strlen("Hello)+1) * sizeof(char));

strcpy(string, "Hello");
```



Arrays of pointers

- We can declare an array of pointers like so:

```
char *name[]= {"John", "Jay", "Joe"};
/* Creates and initialises 3 names */
```

We can now use the array elements anywhere we could use a string.

Example

```
int i;
char *people[]= {“John", “Jay", “Joe"};
for (i= 0; i < 3; i++} {
    printf ("String %d is %s\n",i,people[i]);
}
```

Output:

```
String 0 is John
String 1 is Jay
String 2 is Joe
```

Structures

- Structures are a way of constructing higher-level types. E.g.

```
struct coordinate {
  int x;
  int y;
} var;

var.x = 1;
var.y = 2;

printf("structure size = %d\n",
  sizeof(struct coordinate));
```

Struct coordinate has 2 members

var is of type "struct coordinate"

Dot notation "." accesses members in struct

Pointers and structures

```
struct coordinate {
   int x;
   int y;
} *var;
```

Variable is a pointer to struct coordinate

```
var = (struct coordinate *)malloc(sizeof(struct coordinate));
var->x = 1;
var->y = 2;
```

Allocate memory of correct size

Arrow notation "->" accesses members

Pointers and functions

- Functions can return arrays as pointers:

```
int *foo(void)
{
  static int array[100];
  …
  return array;
}
```

Returns array to invoker

Why is this okay?

Pointers and functions

- C passes by value, so there is no direct way for the called function to alter a variable in the calling function

```
swap(a,b);
    .
    .
    .
void swap(int x, int y) /* WRONG */
    {
      int temp;
      temp = x;
      x = y;
      y = temp;
    }
```

Pointers and functions

- Because of call by value, swap cannot affect the arguments a and b.
- We must use pointers!

```
swap(&a,&b);
    .
    .
    .
void swap(int *px, int *py) /* interchange *px and *py */
   {
     int temp;
     temp = *px;
     *px = *py;
     *py = temp;
   }
```

Pointers and functions

- Functions can also return structs as a pointer:

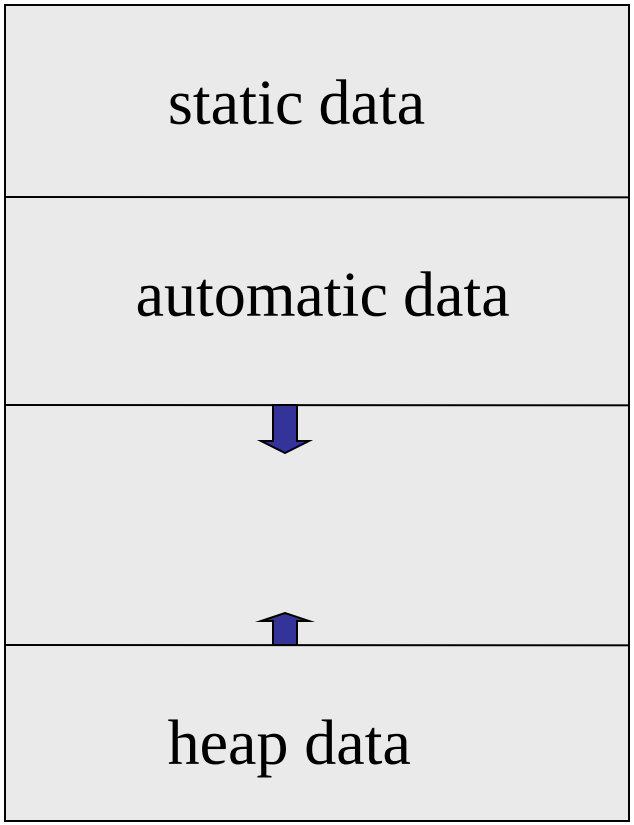
```
struct coordinate *foo(void)
{
   struct coordinate *tmp;
   tmp  = (struct coordinate *)malloc(sizeof(struct coordinate));
   return tmp;
}
```

Returns heap allocated struct to invoker

Memory model

- Properties of variable determined by type, scope and life-time
- Life-time of a variable:
  - Static: starts and ends with program
    - Global and static variables
  - Automatic: starts and ends in block
    - Local and stack allocated variables
  - Heap: starts when allocated, ends with freed
    - Dynamically allocated variables

Memory model



Pre-allocated at compile time

Variables are allocated on stack as blocks are entered and de-allocated as blocks leave. Usually grows downwards (address-wise).

Variables are allocated in area at the bottom of the address space. May be organized specifically to optimize re-use as life-time of variables can be arbitrary.

Automatic memory allocation

```
void foo(void)
{
   int local_var = 1;
   printf("Local=%d\n", local_var++);
}

foo();
foo();
```

← **Allocated at function startup and visible only in block**

Output:
Local=1
Local=1

Static memory allocation

```
int g_var1 = 1;
static int g_var2 = 1;
void foo(void)
{

   static int s_var = 1;
   printf("Local=%d, Global=%d\n", s_var++, g_var2++);
}

foo();
foo();
```

Allocated at program startup and visible everywhere

Allocated at program startup and only visible within file

Allocated at program startup but only visible in block

Output:
Local=1, Global=1
Local=2, Global=2

en.wikipedia.org/wiki/Static_variable

Allocating memory on heap

- We can allocate memory on the heap with the `malloc()` function:

```
p = (int *)malloc(sizeof(int));
```

Cast to appropriate type

sizeof(int) returns how many bytes an int type requires

Resizing memory on heap

- We can resize memory on the heap with the `realloc()` function:

```
int *p;
double *q;

p = (int *)malloc(sizeof(int));

q = (double *)realloc(p, sizeof(double));
```

New size

Previously allocated heap storage

Freeing memory on heap

- You can free memory on the heap with the `free()` function:

```
void free(void *ptr);
```

Function prototype in stdlib.h

```
int *p = (int *)malloc(sizeof(int));
```

Allocate memory of size of integer

```
/* use pointer p */
free(p);
```

After use … free it

Dynamic automatic memory allocation

```
void foo(void)
{
   int *local_var = (int *)alloca(sizeof(int));

}
```

cast

Size of space requested

Memory space automatically de-allocated when execution leaves block (free is not necessary)

Common mistake (1)

```
char *foo(void)
{
    char *string = "hello world";
    return string;
}

char *mystring;
mystring = foo();
…
printf("mystring = %s\n", mystring);
```

Returns memory to automatic variable

Could crash because foo() returns string in automatic storage area

Common mistake (2)

```
void foo(int *data)
{
   …
   free(data);
}

int *mydata = (int *)malloc(sizeof(int));
foo(mydata);
free(mydata);
```

Heap storage free'd twice!

Common mistake (3)

```
void foo(void)
{
  int *pt = (int *)malloc(sizeof(int));
  …
  return;
}

foo();
foo();
foo();
```

Memory Leak! May eventually crash.

Allocate a 2-D array

```
int  **A;
int A_rows = 3;
int A_cols = 2;

A = malloc(A_rows * sizeof(int *));
If(A == NULL){
   printf("cannot allocate memory!\n");
   exit(-1);
}

for(i=0; i< A_rows; i++){
   A[i] = malloc(A_cols * sizeof(int));
}
```

Allocate memory for all rows

For each row allocate The entire column

A function using a 2-D array argument

```
//prototype
void 2d_func(int **A);

//function define:
void 2d_func(int **A){
  printf("the value at 0,0 is:  %d\n", A[0][0]);
}
```

De-allocate a 2-D array

```
//free allocated memory when finished
for(i=0; i<A_rows; i++){
   free(A[i]);
}
free(A);
```

Homework 6

Using Dynamic Memory allocation & Functions

- Write a program that performs a matrix multiply inside of a function.
- You will have four functions in this program, main(), check(), matmul(), and printResult().
- In the main function you can initialize the matrix by reading values from the keyboard or you can hard-code the values.
- Use the check() function to determine if the two matrices can be multiplied, exit the program if they cannot.
- Pass your matrixA and matrixB to the function matmul(), which will perform the matrix multiply then print the result using the printResult() function.