Computer Programming

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07: Pointers and addresses: pass by reference, pointer arithmetic

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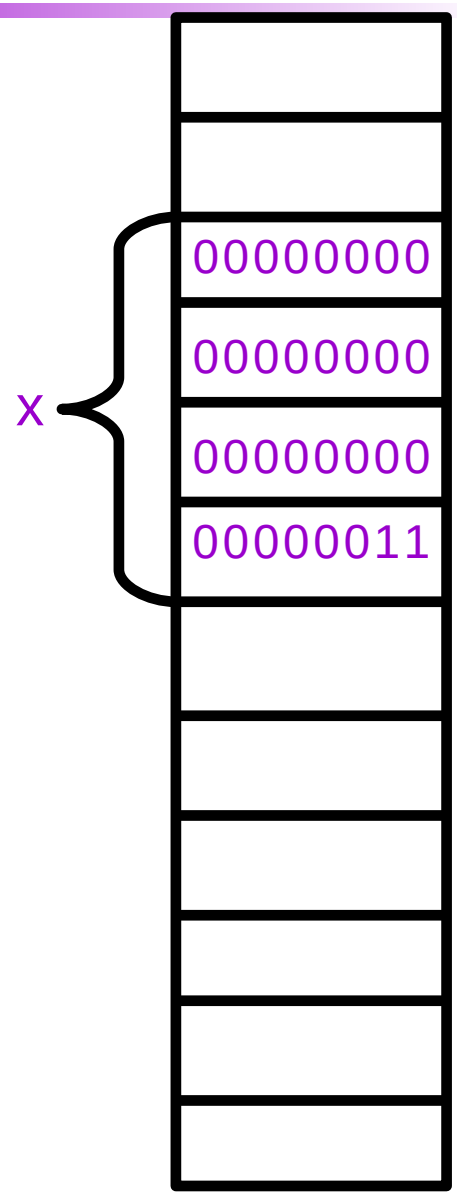
Contents

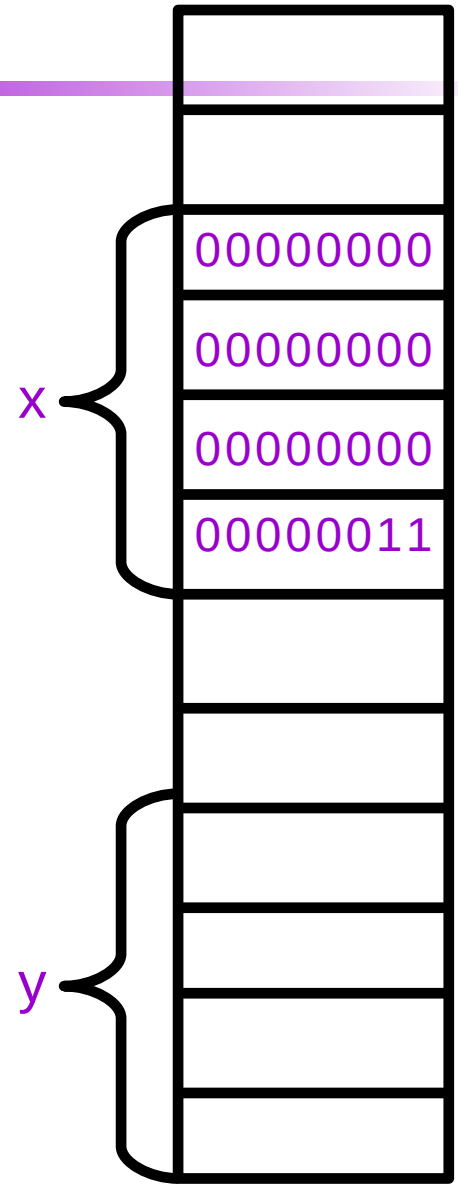
Pointer Fundamentals

- When a variable is defined the compiler (linker/ loader actually) allocates a real memory address for the variable.
  - int x; will allocate 4 bytes in the main memory, which will be used to store an integer value.
- When a value is assigned to a variable, the value is actually placed to the memory that was allocated.
  - x= 3; will store integer 3 in the 4 bytes of memory.



Pointers

- When the value of a variable is used, the contents in the memory are used.
  - y= x; will read the contents in the 4 bytes of memory, and then assign it to variable y.
- &x can get the address of x. (referencing operator &)
- The address can be passed to a function:
  - scanf("%d", &x);
- The address can also be stored in a variable ……



Pointers

- To declare a pointer variable

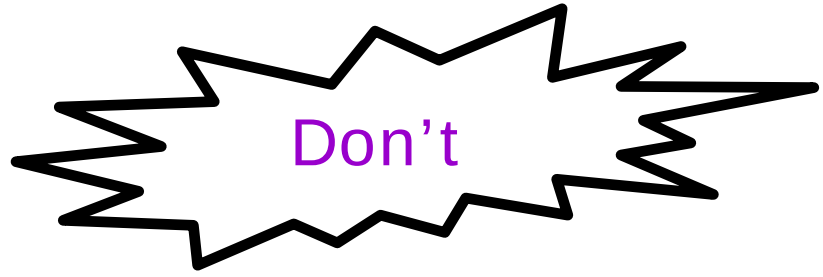
  type * pointername;

- For example:
  - int * p1; p1 is a variable that tends to point to an integer, (or p1 is a int pointer)
  - char *p2;
  - unsigned int * p3;
- p1 = &x; /* Store the address in p1 */
- scanf("%d", p1); /* i.e. scanf("%d",&x); */
- p2 = &x; /* Will get warning message */

Initializing Pointers

- Like other variables, always initialize pointers before using them!!!
- For example:

```
int main(){
   int x;
   int *p;
   scanf("%d",p);   /*
      */
   p = &x;
   scanf("%d",p);  /* Correct */
}
```



Using Pointers

- You can use pointers to access the values of other variables, *i.e.* the contents of the memory for other variables.
- To do this, use the * operator (dereferencing operator).
  - Depending on different context, * has different meanings.
- For example:

```
int n, m=3, *p;
p=&m;
n=*p;
printf("%d\n", n);
printf("%d\n",*p);
```

An Example

```
int m=3, n=100, *p;
p=&m;
printf("m is %d\n",*p);
m++;
printf("now m is %d\n",*p);
p=&n;
printf("n is %d\n",*p);
*p=500;    /* *p is at the left of "="  */
printf("now n is %d\n", n);
```

Pointers as Function Parameters

- Sometimes, you want a function to assign a value to a variable.
  - e.g. scanf()
- E.g. you want a function that computes the minimum AND maximum numbers in 2 integers.
- Method 1, use two global variables.
  - In the function, assign the minimum and maximum numbers to the two global variables.
  - When the function returns, the calling function can read the minimum and maximum numbers from the two global variables.
- This is bad because the function is not reusable.

Pointers as Function Parameters

- Instead, we use the following function

```
void min_max(int a, int b,
        int *min, int
    *max){
    if(a> b){
        *max= a;
        *min= b;
    }
     else{
        *max= b;
        *min= a;
    }
}
```

```
int main()
{
    int x,y;
    int small,big;
    printf("Two integers: ");
    scanf("%d %d", &x, &y);

    min_max(x,y,&small,&big
    );
    printf("%d <= %d", small,
    big);
    return 0;
}
```

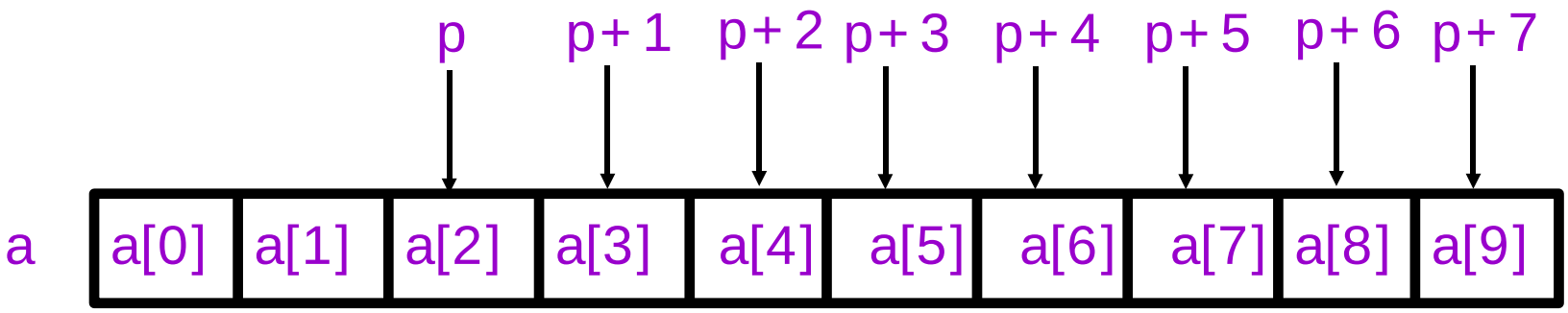
Pointer Arithmetic (1)

When a pointer variable points to an array element, there is a notion of adding or subtracting an integer to/from the pointer.

```
int a[ 10 ], *p;
p = &a[2];
*p = 10;
*(p+1) = 10;
printf("%d", *(p+3));
```

```
int a[ 10 ], *p;


a[2] = 10;
a[3] = 10;
printf("%d", a[5]);
```



Pointer Arithmetic (2)

- More examples:

```
int a[10], *p, *q;
p = &a[2];
q = p + 3;          /* q points to a[5] now */
p = q – 1;          /*  p points to a[4] now */
p++;               /*  p points to a[5] now */
p--;                     /* p points to a[4] now */
*p = 123;           /*  a[4] = 123 */
*q = *p;           /*   a[5] = a[4]   */
q = p;             /*   q points to a[4] now */
scanf("%d", q)    /* scanf("%d", &a[4])  */
```

Pointer Arithmetic (3)

- If two pointers point to elements of a same array, then there are notions of subtraction and comparisons between the two pointers.

```
int a[10], *p, *q , i;
p = &a[2];
q = &a[5];
i = q - p;        /* i is 3*/
i = p - q;        /* i is -3 */
a[2] = a[5] = 0;
i = *p - *q;      /* i = a[2] – a[5]  */
p < q;            /* true */
p == q;           /* false */
p != q;           /* true */
```

Pointers and Arrays

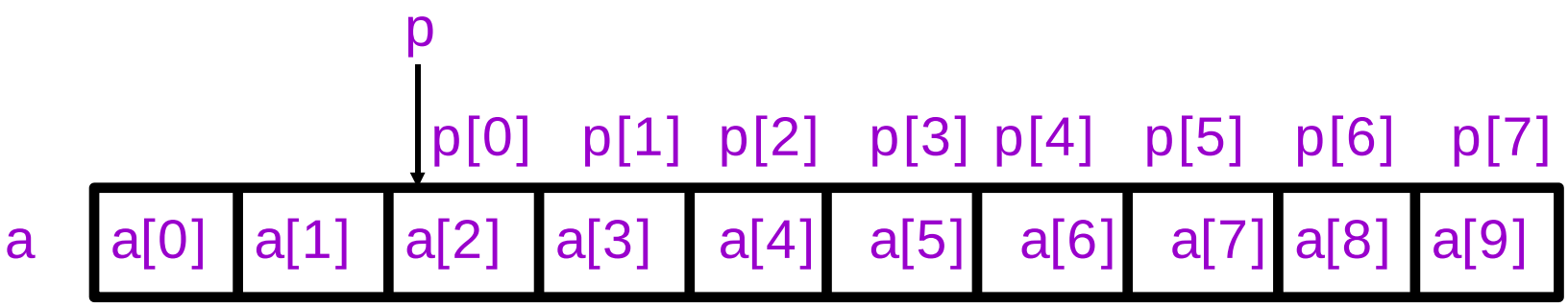
- Recall that the value of an array name is also an address.
- In fact, pointers and array names can be used interchangeably in many (but not all) cases.
  - E.g. `int n, *p;  p=&n;`
  - `n=1;  *p = 1;  p[0] = 1;`
- The major differences are:
  - Array names come with valid spaces where they "point" to. And you cannot "point" the names to other places.
  - Pointers do not point to valid space when they are created. You have to point them to some valid space (initialization).

Using Pointers to Access Array Elements

```
int a[ 10 ], *p;
p = &a[2];
p[0] = 10;
p[1] = 10;
printf("%d", p[3]);
```

```
int a[ 10 ], *p;


a[2] = 10;
a[3] = 10;
printf("%d", a[5]);
```



An Array Name is Like a Constant Pointer

- Array name is like a constant pointer which points to the first element of the array.

```
int a[10], *p, *q;
p = a;          /* p = &a[0] */
q = a + 3;      /* q = &a[0] + 3 */
a++;            /*  illegal !!! */
```

- Therefore, you can “pass an array” to a function. Actually, the address of the first element is passed.

```
int a[ ] = { 5, 7, 8 , 2, 3 };
sum( a, 5 );  /* Equal to sum(&a[0],5)  */
.....
```

An Example

```
/* Sum – sum up the ints
   in the given array */
int sum(int *ary, int size)
{
   int i, s;
   for(i = 0, s=0;
   i<size;i++){
        s+=ary[i];
   }
   return s;
}
```

```
/* In another
   function */
   int a[1000],x;
   ......
   x=
   sum(&a[100],50);
   /* This sums up
   a[100], a[101], ...,
   a[149] */
```

Allocating Memory for a Pointer (1)

- The following program is wrong!

```
#include <stdio.h>
int main()
{
   int *p;
   scanf("%d",p);
   return 0;
}
```

- This one is correct:

```
#include <stdio.h>
int main()
{
   int *p;
   int a;
   p = &a;
   scanf("%d",p);
   return 0;
}
```

Allocating Memory for a Pointer (2)

- There is another way to allocate memory so the pointer can point to something:

```
#include <stdio.h>
#include <stdlib.h>
int main(){
   int *p;
   p = (int *) malloc( sizeof(int) );   /* Allocate 4 bytes */
   scanf("%d", p);
   printf("%d", *p);
   free(p);      /* This returns the memory to the
   system.*/
                 /* Important !!! */
}
```

Allocating Memory for a Pointer (3)

- Prototypes of malloc() and free() are defined in stdlib.h

```
void * malloc(size_t number_of_bytes);
void free(void * p);
```

- You can use malloc and free to dynamically allocate and release the memory;

```
int *p;
p = (int *) malloc(1000 * sizeof(int) );
for(i=0; i<1000; i++)
    p[i] = i;
p[1000]=3;   /* Wrong! */
free(p);
p[0]=5;   /* Wrong! */
```

An Example – Finding Prime Numbers

```
#include <stdio.h>
#include <stdlib.h>
/* Print out all prime
numbers which are less
than m */
void print_prime( int m )
{
  int i,j;
  int * ary =  (int *) malloc( m * sizeof(int));
  if (ary== = NULL) exit - 1;
  for(i= 0;i< m;i+ + )
    ary[i]= 1;
  /* Assume all integers between 0 and
m- 1 are prime */
  ary[0]= ary[1]= 0;
  /* Note that in fact 0 and 1 are not
prime */
  for(i= 3;i< m;i+ + ){
    for( j= 2; j< i; j+ + )
      if(ary[ i ] && i%j= = 0){
ary[i]= 0;
break;
      }
  }
  for(i= 0;i< m;i+ + )
    if(ary[i]) printf("%d ", i);
  free( ary );
  printf("\n");
}

int main() {
  int m;
  printf("m =  ");
  scanf("%d", &m);
  printf("\n");
  print_prime(m);
  return 0;
}
```

References I

[1] MinGW Installation Notes Wiki Page, May 2007. URL http://www.mingw.org/wiki/Getting_Started. Accessed 18 June 2019.

[2] MSYS Wiki Page, January 2008. URL http://www.mingw.org/wiki/MSYS. Accessed 18 June 2019.

[3] Eclipse Foundation. Eclipse Project. URL https://www.eclipse.org/.

[4] Chua Hock-Chuan. Yet another insignificant . . . programming notes, March 2019. URL https://www3.ntu.edu.sg/home/ehchua/programming/index.html. Accessed 18 June 2019.

[5] Marc Moreno Maza. Lecture notes: Software tools and systems programming. University of Western Ontario, 2011.

[6] Daniel Weller and Sharat Chikkerur. 6.087 Practical Programming in C. Massachusetts Institute of Technology: MIT OpenCourseWare, January 2010. URL https://ocw.mit.edu. License: Creative Commons BY-NC-SA.