Pointers

March 19, 2012

Outline

Pointers

Pointers are variables, which contain the address of some other variables.

Declaration: *datatype* *pointername;
e.g. long * ptra;

The *type* of a pointer depends on the type of the variable it points to. Every pointer points to some data type.

Sizes of basic data types

All data is stored in memory. But different data types occupy different amount of memory.

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For example, on some machine you may have

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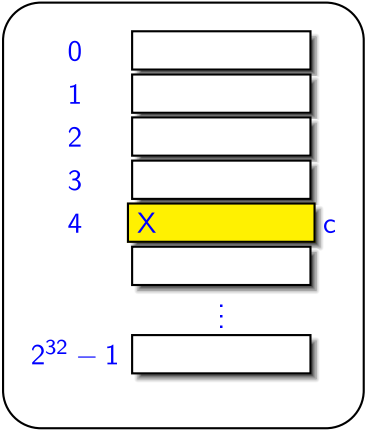
These numbers are NOT the same for all machines. You should use the `sizeof()` operator instead of assuming the value.

A Sample Program



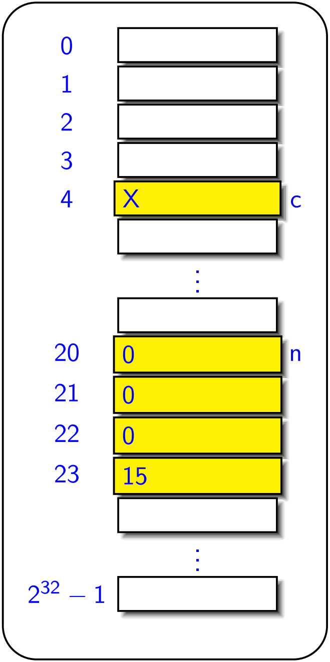
Memory Layout (Bytes)

```c
#include <stdio.h>

int main()
{
    int n;
    char c;
    int *ptrn;

    c='X';
    n=15;
    ptrn=&n;

    return 0;
}
```

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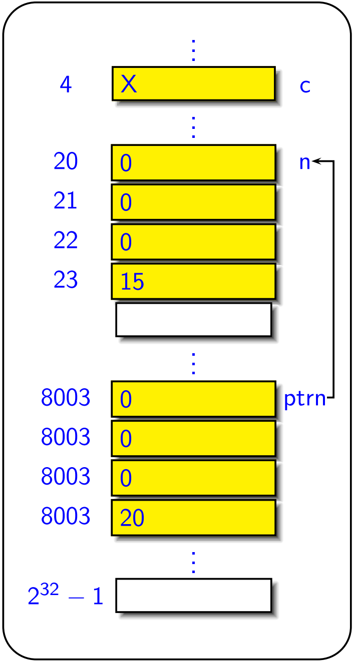


```c
#include <stdio.h>

int main()
{
    int n;
    char c;
    int *ptrn;

    c='X';
    n=15;
    //address of n
    //sizeof(ptrn) = 4
    ptrn=&n;


    return 0;
}
```

sizeof(ptrn) = 4 bytes = 32 bits, since we have 2^{32} byte addresses.

Address Operations

There are two unary operations to consider.

- The * operator: If `ptra` is a pointer variable, then `*ptra` gives you the content of the location pointed to by ptr.

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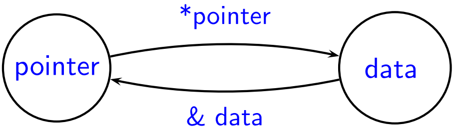

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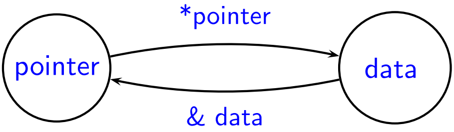

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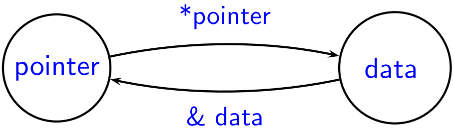

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Caution: Declaration of a pointer also uses '*'.

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Unary Pointer Arithmetic Operators

- Operator ++: Adds `sizeof(datatype)` number of bytes to pointer, so that it points to the next entry of the datatype.
- Operator −−: Subtracts `sizeof(datatype)` number of bytes to pointer, so that it points to the next entry of the datatype.

Pointer Arithmetic - Example 1

```c
#include <stdio.h>

int main()
{
    int *ptrn;
    long *ptrlng;

    ptrn++;        //increments by sizeof(int) (4 bytes)
    ptrlng++;      //increments by sizeof(long) (8 bytes)

    return 0;
}
```

Pointer Arithmetic - II

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1. ptrlng+n is valid, if n is an integer. The result is the following byte address
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2. `ptrlng-n` is similar.

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2. `ptr1 - ptr 2` is allowed, as long as they are pointing to elements of the same array. The result is

$$\frac{\texttt{ptr1 - ptr2}}{\texttt{sizeof}(\textit{datatype})}$$

In other settings, this operation is undefined (may or may not give the correct answer).

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   In other settings, this operation is undefined (may or may not give the correct answer).

Why all these special cases? These rules for pointer arithmetic are intended to handle addressing inside arrays correctly.

Pointer Arithmetic - IV

If we can subtract a pointer from another, all the relational operations can be supported!

Logical Operations on Pointers

1. `ptr1` $>$ `ptr2` is the same as `ptr1 - ptr2 > 0`,
2. `ptr1` $=$ `ptr2` is the same as `ptr1 - ptr2 = 0`,
3. `ptr1` $<$ `ptr2` is the same as `ptr1 - ptr2 < 0`,
4. and so on.

Outline

Arrays and Pointers

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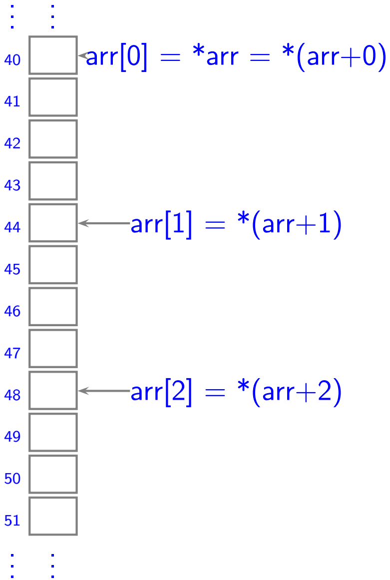
4. `*(arr+i)`, is equal to `arr[i]`.
5. Question: What is `&arr[i]` equivalent to?

Arrays and Pointers - Figure




```
int arr[3];
```

Outline

Passing Pointers to Functions

Since pointers are also variables, they can be passed

- As input parameters to functions
- As return values from functions

Passing Pointers - Reason 1

Why do we pass pointer variables to functions?

Recall the swap function which took input integers. This function was unable to swap the variables inside `main()`.

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Recall the swap function which took input integers. This function was unable to swap the variables inside `main()`.

Suppose we want a swap function which is able to swap arguments inside the caller.

Main idea: Pass pointers!!

A Swap Program

```
#include <stdio.h>

//Swap the contents of locations pointed to by the
//input pointers
void swap(int *pa, int *pb)
{
    int temp;

    temp = *pb;
    *pb    = *pa;
    *pa    = temp;
    return;
}

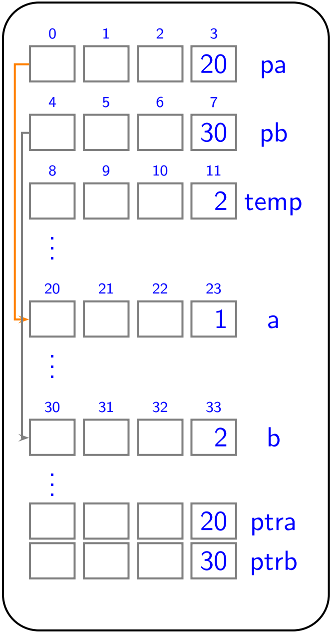
int main()
{
   int a = 1, b = 2;
   int *ptra = &a;
   int *ptrb = &b;

   printf(``a=%d b=%d'', a, b);

   swap (ptra, ptrb);     //equivalently, swap(&a, &b);

   //a and b would now be swapped
   printf(``a=%d b=%d'', a, b);
   return 0;
}
```

When `swap(pa, pb)` is called, the value of the pointers is copied to the function. The value of the pointers is the address of a and b, respectively.

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void swap(int *pa, int *pb)
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    int temp;
    temp = *pb;
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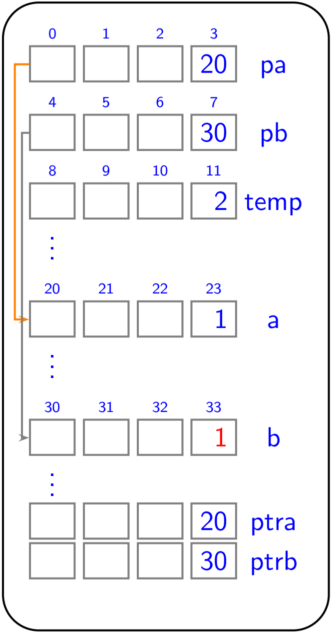
```

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void swap(int *pa, int *pb)
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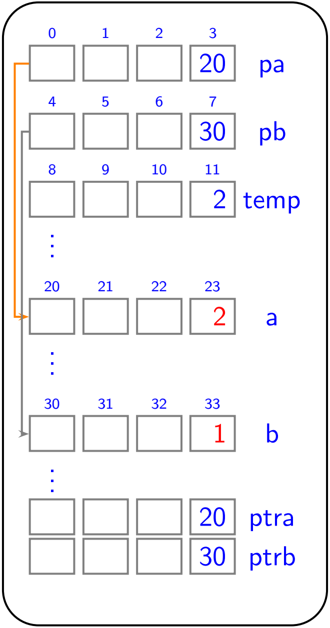


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scanf(‘‘%d’’, &n);
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printf

```
printf(``%d'',n);
```

`printf` does not need to change the content of `n`.

Passing arrays to functions

We have already seen that we can pass arrays as input to functions. We also have seen that arrays are essentially pointers.

We can pass pointers, where arrays are expected, and vice versa!

Passing arrays to functions

```
#include <stdio.h>

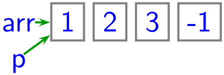
//Count number of elements in an integer array,
//until the first -1
int num_elts(int *a)
{
        int *p;
        p = a;

        while(*p != -1){
                p++;
        }

        return p-a;
}

int main()
{
        int arr[] = {1, 2, 3, -1};
        printf("%d", num_elts(arr)); //Passing array as pointer
        return 0;
}
```

Schematic Diagram of num_elts



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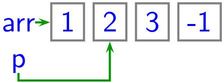

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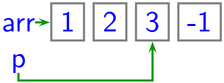

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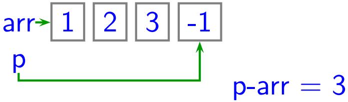

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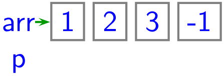

If we changed the call to the following line,

```
num_elts(arr+1);
```

the result is 2, since the num_elts will search in the subarray {2,3,-1}.

Passing Pointers to Functions - Another Reason

Passing a pointer to data, instead of passing the value of the data can be much faster.

This is used to reduce the slowdown due to function calling.

The decision to do this must be taken with care.

Common Mistakes in Pointer Programs

Programming with pointers has to be done with care. Common mistakes include

1. Crossing array boundaries - Suppose an array has 10 elements, and arr is pointing to the first element. If you do *(arr-1), or *(arr+11), you might get unpredictable behaviour.
2. “Dangling Pointers” - pointers that point to data that is not meaningful - for example, using a pointer without initializing it.

Debugging Pointer Programs

If there is an error in a program using pointers, when executing, you will most probably get "Segmentation Fault".

There are several ways to find the error.

1. Go through the code carefully and see if you can locate the bug. (perfect!)

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3. Insert printf statements to pinpoint where the code crashes. (When doing so, make sure to put "\n" at the end of the message - it might not print otherwise!)

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Debugging using printf statements - Example

```
void merge_p(int *s, int *t, int *result, int size_s, int size_t)
{
        int *p = s;
        int *q = t;

        printf("Reached Point 0\n");


        while(p-s<size_s && q-t<size_t){
            //...
        }

        printf("Reached Point 1\n");

        if(p-s < size_s){
                while( p-s < size_s) {
                    //...
                }
        }else if(q-t < size_t){
                while( q-t < size_t) {
                    //...
                }
        }

        printf("Reached Point 2\n");

        return;

}
```