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CS61C : Machine Structures

Lecture #4: Strings & Structts

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Andy Carle

Review: Arrays

- Arrays are (almost) identical to pointers
  - `char *string` and `char string[]` are nearly identical declarations
    - They differ in subtle ways: incrementing, declaration of filled arrays
    - Key Difference: an array variable is a CONSTANT pointer to the first element.
  - ar[i] ←→ *(ar+i)

Review: Arrays and Pointers

- Array size `n`; want to access from `0` to `n-1`:

Array Indexing Versions:

```
#define ARSIZE 10
int ar[ARSIZE];
int i=0, sum = 0;

...
while (i < ARSIZE)
        sum += ar[i++];

    or

while (i < ARSIZE)
        sum += *(ar + i++);
```

Pointer Indexing Version:

```
#define ARSIZE 10
int ar[ARSIZE];
int *p = ar, *q = &ar[10]*;
int sum = 0;

...
while (p < q)
        sum += *p++;
```

* C allows 1 past end of array!

Review: Common C Errors

- There is a difference between assignment and equality
  - `a = b` is assignment
  - `a == b` is an equality test
- This is one of the most common errors for beginning C programmers!
- Precedence Rules
  - int **a = {{1, 2}, {3, 4}}
  - *a[1]++;   ([ ] > *)

Topic Outline

- Strings
- Handles
- Structs
- Heap Allocation Intro
- Linked List Example

C Strings (1/3)

- A string in C is just an array of characters.

```
char string[] = "abc";
```

- How do you tell how long a string is?
  - Last character is followed by a 0 byte (null terminator)

```
int strlen(char s[])
{
    int n = 0;
    while (s[n] != 0) n++; /* '\0' */
    return n;
}
```

C Strings Headaches (2/3)

- One common mistake is to forget to allocate an extra byte for the null terminator.
- More generally, C requires the programmer to manage memory manually (unlike Java or C++).
  - When creating a long string by concatenating several smaller strings, the programmer must insure there is enough space to store the full string!
  - What if you don't know ahead of time how big your string will be?
- String constants are immutable:
  - char *f = "abc"; f[0]++; /* illegal */
    - Because section of mem where "abc" lives is immutable.
  - char f [ ] = "abc"; f[0]++; /* Works! */
    - Because, in declaration, c copies abc into space allocated for f.

C String Standard Functions (3/3)

- `int strlen(char *string);`
  - compute the length of `string`
- `int strcmp(char *str1, char *str2);`
  - return 0 if `str1` and `str2` are identical (how is this different from `str1 == str2`?)

`char *strcpy(char *dst, char *src);`
  - copy the contents of string `src` to the memory at `dst` and return `dst`. The caller must ensure that `dst` has enough memory to hold the data to be copied.

Pointers to pointers (1/4) …review…

- Sometimes you want to have a procedure increment a variable?
- What gets printed?

```
void AddOne(int  x)                y = 5
{     x =  x + 1;   }

int y = 5;
AddOne( y);
printf("y = %d\n", y);
```


Pointers to pointers (2/4) …review…

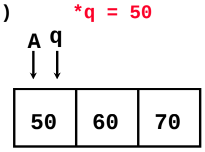
- Solved by passing in a pointer to our subroutine.
- Now what gets printed?

```
void AddOne(int *p)                y = 6
{    *p = *p + 1;   }

int y = 5;
AddOne(&y);
printf("y = %d\n", y);
```


Pointers to pointers (3/4)

- But what if what you want changed is a pointer?
- What gets printed?

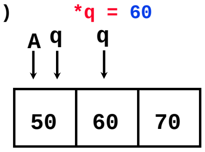
```
void IncrementPtr(int  *p)     *q = 50
{    p =  p + 1;    }

int A[3] = {50, 60, 70};
int *q = A;
IncrementPtr( q);
printf("*q = %d\n", *q);
```



Pointers to pointers (4/4)

- Solution! Pass a pointer to a pointer, called a handle, declared as `**h`
- Now what gets printed?

```
void IncrementPtr(int **h)     *q = 60
{   *h = *h + 1;    }

int A[3] = {50, 60, 70};
int *q = A;
IncrementPtr(&q);
printf("*q = %d\n", *q);
```



C structures : Overview (1/3)

- A `struct` is a data structure composed of simpler data types.
  - Like a class in Java/C++ but without methods or inheritance. Don't get hung up on this comparison.

```
struct point {
    int x;
    int y;
};
void PrintPoint(struct point p)
{
    printf("(%d,%d)", p.x, p.y);
}
```


C structures: Pointers to them (2/3)

- The C arrow operator (`->`) dereferences and extracts a structure field with a single operator.
- The following are equivalent:

```
struct point *p;

printf("x is %d\n", (*p).x);
printf("x is %d\n", p->x);
```


How big are structs? (3/3)

- Recall C operator `sizeof()` which gives size in bytes (of type or variable)
- How big is `sizeof(p)`?

```
struct p {
    char x;
    int y;
};
```

5 bytes? 8 bytes?
Compiler may word align integer y

Dynamic Memory Allocation (1/4)

- C has operator `sizeof()` which gives size in bytes (of type or variable)
- Assume size of objects can be misleading & is bad style, so use `sizeof(type)`
  - Many years ago an `int` was 16 bits, and programs assumed it was 2 bytes

Dynamic Memory Allocation (2/4)

- To allocate room for something new to point to, use `malloc()` (with the help of a typecast and `sizeof`):

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

  - Now, `ptr` points to a space somewhere in memory of size `(sizeof(int))` in bytes.
  - `(int *)` simply tells the compiler what will go into that space (called a typecast).
- `malloc` is almost never used for 1 var

```
ptr = (int *) malloc (n*sizeof(int));
```

  - This allocates an array of n integers.

Dynamic Memory Allocation (3/4)

- Once `malloc()` is called, the memory location might contain anything, so don't use it until you've set its value.
- After dynamically allocating space, we must dynamically free it:

```
free(ptr);
```

- Use this command to clean up.
  - OS keeps track of size to free.

Dynamic Memory Allocation (4/4)

- Malloc does <u>not</u> always succeed.
  - System could be out of memory
  - An error occurred during the memory request
  - Operating system just doesn't like you today…
- <u>Always</u> check the pointer you get back to make sure it is not NULL.
  - int *p;
    ```
    if ((p = (int*) malloc(10 * sizeof(int))) == NULL) {
      /*do something to recover */
    }
    ```


Binky Pointer Video (thanks to NP @ SU)

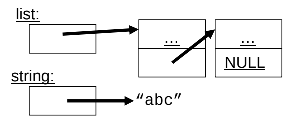
Linked List Example

- Let's look at an example of using structures, pointers, `malloc()`, and `free()` to implement a linked list of strings.

```
struct Node {
     char *value;
     struct Node *next;
};
typedef Node *List;

/* Create a new (empty) list */
List ListNew(void)
{ return NULL; }
```


Linked List Example

```
/* add a string to an existing list */
List list_add(List list, char *string)
{
  struct Node *node =
    (struct Node*) malloc(sizeof(struct Node));
  node->value =
    (char*) malloc(strlen(string) + 1);
  strcpy(node->value, string);
  node->next = list;
  return node;
}
```



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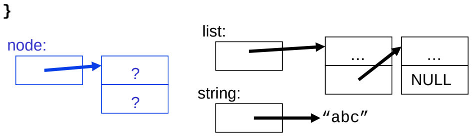

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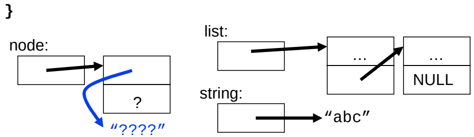

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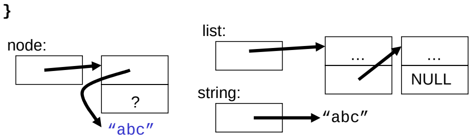

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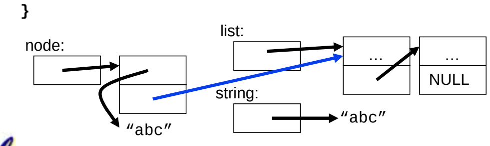

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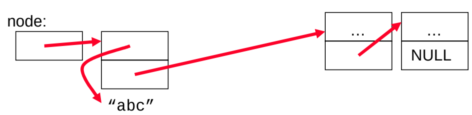

“And in Conclusion…”

- Use handles to change pointers
- Create abstractions with structures
- Dynamically allocated heap memory must be manually deallocated in C.
  - Use `malloc()` and `free()` to allocate and deallocate memory from heap.