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CS61C : Machine Structures

Lecture 5 – C Memory Management

2004-01-30

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3D ⇒ Super Bowl (You'll need 3D glasses)

NY Times

Clarifications to Wednesday's lecture

1. `#define` macros may go anywhere. Thereafter the name is replaced with the replacement text. It is usually good style to put all `#define`s at the top so that reordering code doesn't cause bugs.
2. `void *` pointers used to be `char *` pointers (before ANSI C). Therefore, partially to maintain compatibility, `++` incrementing a `void *` pointer via increments it by 1 byte.
3. `const` type qualifier announces objects are not to be changed. Implementation-dependent storage and violation penalty.

C String Standard Functions

- `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`?)
- `int strcpy(char *dst, char *src);`
  - copy the contents of string `src` to the memory at `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)
{     x =  x + 1;   }

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

`y = 5`

Pointers to pointers (2/4) …review…

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

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

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

`y = 6`

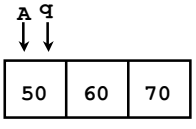
Pointers to pointers (3/4)

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

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

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

`*q = 50`



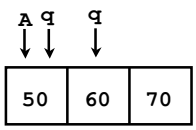
Pointers to pointers (4/4)

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

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

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

*q = 60



Administrivia

- Read K&R 7.8.5, 8.7, Paul Hilfinger's notes 10.1-10.4 (on www) for Monday
- Midterm: 2004-03-08 @ 7pm-10pm
  - It'll be in 155 Dwinelle
  - Review session TBA
- One extra credit lab checkoff pt!
  - Sign up to get your lab checked off by the first hour and you will get 1 bonus checkoff point to count toward final grade. (Not 1/300, +1 out of 4 for that lab)
- Reading quizzes answered in disc, OH

Dynamic Memory Allocation (1/3)

- 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 (2/3)

- 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.

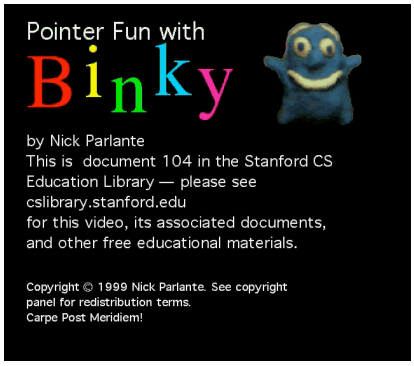
Dynamic Memory Allocation (3/3)

- 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.

Binky Pointer Video (thanks to NP @ SU)



C structures : Overview

- A `struct` is a data structure composed for simpler data types.
  - Like a class in Java/C++ but without methods or inheritance.

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

C structures: Pointers to them

- 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?

- 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

Peer Instruction

Which are guaranteed to print out 5?

```
I:   main() {
       int *a-ptr; *a-ptr = 5; printf("%d", *a-ptr); }

II:  main() {
       int *p, a = 5;
       p = &a; ...
       /* code; a & p NEVER on LHS of = */
       printf("%d", a); }

III: main() {
       int *ptr;
       ptr = (int *) malloc (sizeof(int));
       *ptr = 5;
       printf("%d", *ptr); }
```

	I	II	III
1:	–	–	–
2:	–	–	YES
3:	–	YES	–
4:	–	YES	YES
5:	YES	–	–
6:	YES	–	YES
7:	YES	YES	–
8:	YES	YES	YES

Linked List Example

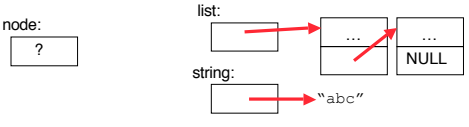
- Let's look at an example of using structures, pointers, `malloc()`, and `free()` to implement a linked list of strings.

```
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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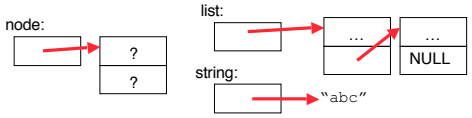

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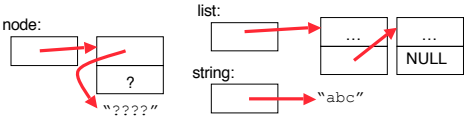

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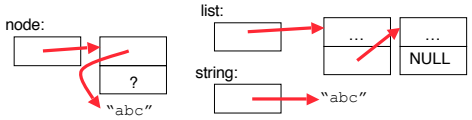

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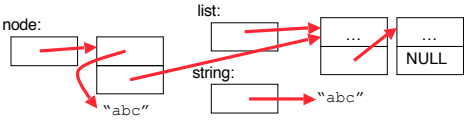

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  node->next = list;
  return node;
}
```

"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.