



Memory Allocation

CS 217



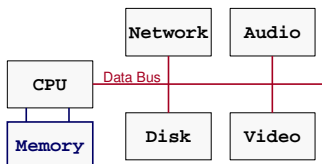
Memory Allocation

- Good programmers make efficient use of memory
- Understanding memory allocation is important
 - Create data structures of arbitrary size
 - Avoid "memory leaks"
 - Run-time performance



Memory

- What is memory?
 - Storage for variables, data, code, etc.



Memory

- What is memory?
 - Storage for variables, data, code, etc.
 - Unix provides virtual memory

0
Virtual Address Space
0xffffffff

Memory Layout

- How is memory organized?
 - Text = code
 - Data = constants
 - BSS = global and static variables
 - Stack = local variables
 - Heap = dynamic memory

0
Text
Data
BSS
Heap
↓
Stack
↑
0xffffffff

Memory Layout

```

int isize;           ← bss

char *f(void)
{
    char *p;         ← stack
    isize = 8;      ← data
    p = malloc(isize); ← heap
    return p;
}

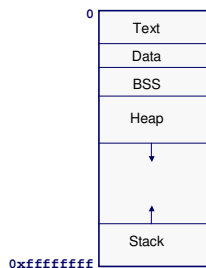
```

0
Text
Data
BSS
Heap
↓
Stack
↑
0xffffffff

Memory Allocation



- How is memory allocated?
 - Global and static variables = program startup
 - Local variables = function call
 - Dynamic memory = malloc()



Memory Allocation



```
int isize;           ← allocated in BSS, set to zero at startup
char *f(void)
{
    char *p;         ← allocated on stack at start of function f
    isize = 8;
    p = malloc(isize); ← 8 bytes allocated in heap by malloc
    return p;
}
```

Memory Deallocation



- How is memory deallocated?
 - Global and static variables = program finish
 - Local variables = function return
 - Dynamic memory = free()
- All memory is deallocated at program termination
 - It is good style to free allocated memory anyway

Memory Deallocation



```
int isize;           ← available until program termination

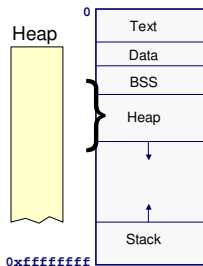
char *f(void)
{
    char *p;        ← deallocated by return from function f
    isize = 8;
    p = malloc(isize); ← deallocate by calling free(p)
    return p;
}
```

Dynamic Memory



```
#include <stdlib.h>
void *malloc(size_t size);
void free(void *ptr);
```

```
char *p1 = malloc(3);
char *p2 = malloc(1);
char *p3 = malloc(4);
free(p2);
char *p4 = malloc(6);
free(p3);
char *p5 = malloc(2);
free(p1);
free(p4);
free(p5);
```



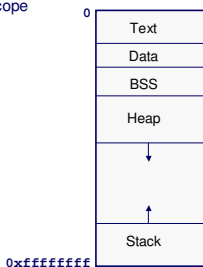
Static Local Variables



- **static** keyword in declaration of local variable means:
 - Available (if within scope) throughout entire program execution
 - Variable is allocated from BSS, not stack
 - Acts like global variable with limited scope

```
int isize;

char *f(void)
{
    static int first = 1;
    if (first) {
        isize = GetSize();
        first = 0;
    }
    ...
}
```



Memory Initialization



- Local variables have undefined values

```
int count;
```

- Memory allocated by malloc has undefined values

```
char *p = malloc(8);
```

- If you need a variable to start with a particular value, use an explicit initializer

```
int count = 0;  
p[0] = '\0';
```

- Global and static variables are initialized to 0 by default

```
static int count = 0;  
is the same as  
static int count;
```

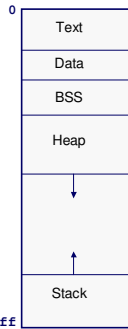
It is bad style to depend on this

Example Program



```
#include <stdio.h>  
#include <string.h>  
  
#define MAX_STRINGS 128  
#define MAX_STRING_LENGTH 256  
  
void ReadStrings(char **strings, int *nstrings, int maxstrings, FILE *fp)  
{  
    char string[MAX_STRING_LENGTH];  
  
    *nstrings = 0;  
    while (!feof(string, MAX_STRING_LENGTH, fp)) {  
        string[(*nstrings)++] = strdup(string);  
        if (*nstrings == maxstrings) break;  
    }  
}  
  
...  
  
int main()  
{  
    char *strings[MAX_STRINGS];  
    int nstrings;  
  
    ReadStrings(strings, &nstrings, MAX_STRINGS, stdin);  
    SortStrings(strings, nstrings);  
    WriteStrings(strings, nstrings, stdout);  
  
    return 0;  
}
```

0xffffffff



Summary



- Three types of memory
 - Global and static variables = BSS
 - Local variables = stack
 - Dynamic memory = heap
- Three types of allocation/deallocation strategies
 - Global and static variables (BSS) = program startup/termination
 - Local variables (stack) = function entry/return
 - Dynamic memory (heap) = malloc()/free()
- Take the time to understand the differences!
