

Laboratory 9

Data Structures Representation

Computer Science 240

Writing X86 Code Directly

Assembly Directives

Begin with a dot and indicate structural information useful to the assembler, linker, or debugger.

```
.data
```

```
//declarations for global variables and literal strings from program go here:  
//for example:
```

```
i: .quad 0 //allocate space for an 8 byte value and initialize to 0  
str: .string "Enter a value" // allocate space and initialize a  
//null-terminated string
```

```
.text
```

```
.globl main
```

```
main: // program instructions go here; your main functions must be declared as  
// global,because it is accessed by other code modules when you run your program
```

There are many others: use a reference to check

Reference: <http://tigcc.ticalc.org/doc/gnuasm.html#SEC67>

Lab Assignment

simple.c: (C code)

```
#include <stdio.h>
```

```
long total = 0;
```

```
int sum(int x,int y) {  
    int t = x + y;  
    total +=t;  
    return t;  
}
```

```
int main() {  
    int x = 2;  
    int y = 3;
```

```
printf("Sum=%d\n",sum(x,y));
```

```
printf("Total = %d\n",total);
```

```
return 0;  
}
```

simple.s: (X86 code)

```
.data //use the data segment of memory
```

```
total: .quad 0 //8 byte value with initial value 0
```

```
fstr1: .string "Sum = %d\n"
```

```
fstr2: .string "Total = %d\n"
```

```
.text
```

```
.globl main
```

```
sum:
```

```
lea (%rsi,%rdi,1),%eax
```

```
add %eax,total
```

```
ret
```

```
main:
```

```
mov $0x3,%esi
```

```
mov $0x2,%edi
```

```
call sum
```

```
mov %eax,%esi
```

```
mov $fstr1,%edi
```

```
mov $0x0,%eax
```

```
call printf
```

```
mov total,%esi
```

```
mov $fstr2,%edi
```

```
mov $0x0,%eax
```

```
call printf
```

```
mov $0x0,%eax
```

```
ret
```

```
#include <stdio.h>
```

```
int z;
```

```
int square(int n) {  
    return n*n;  
}
```

```
int main() {  
    int x = square(3);
```

```
    int y = square(4);
```

```
    z = x + y;
```

```
    printf("Calculation produces  
    %d\n",z);
```

```
    return 0;  
}
```

```
.data
```

```
z:    .long 0  
fstr: .string "Calculation produces %d\n"
```

```
.text  
.globl main
```

```
square: mov %edi,%eax  
        imul %edi,%eax  
        ret
```

```
main:  push %rbx  
        mov $3,%edi  
        call square
```

```
        mov %eax,%ebx  
        mov $4,%edi  
        call square
```

```
        lea (%ebx,%eax,1),%esi  
        mov %esi,z
```

```
        mov $fstr,%edi  
        mov $0,%eax  
        call printf
```

```
        mov $0,%eax  
        pop %rbx  
        ret
```

One-dimensional arrays

Different languages use different implementations at the machine level to represent data structures.

In Java, arrays are actually implemented as arrays of addresses (pointers) to the elements, which are stored elsewhere in memory (not necessarily in contiguous locations).

In C, the elements of the array are stored in a contiguous block, starting at the base address of the array.

In the C model,

address of element in array = base address + element size * index

If the size of the element is limited to 1, 2, or 4 bytes, what is another more efficient way to accomplish the multiplication?

In C, to define some arrays of 8 elements of different sizes:

```
long  qelements[] = {0xF, 0xE, 0xD, 0xC};
int   elements[]  = {0x1, 0x3, 0x5, 0x7, 0x9, 0x11, 0x13, 0x15};
short welements[] = {0x23, 0x25, 0x27, 0x29, 0x31, 0x33, 0x35, 0x37}
char  belements[] = {0x20, 0x30, 0x40, 0x50, 0x60, 0x70, 0x80, 0x90}
```

The equivalent in X86 is:

```
.data
qelements: .quad 0xF,0xE,0xD,0xC
elements:  .long 0x1, 0x3, 0x5, 0x7, 0x9, 0x11,0x13,0x15
welements: .word 0x23,0x25,0x27,0x29,0x31,0x33,0x35,0x37
belements: .byte 0x20,0x30,0x40,0x50,0x60,0x70,0x80,0x90
```

The contents of memory starting at *qelements* displayed using *gdb* would look something like this:

```
0x0049700 <qelements>:      0x00000000 0x0000000F 0x00000000 0x0000000E
0x8049714 <qelements+16>:  0x00000000 0x0000000D 0x00000000 0x0000000C
0x0049724 <elements >:    0x00000001 0x00000003 0x00000005 0x00000007
0x0049734 <elements+16>:  0x00000009 0x00000011 0x00000013 0x00000015
0x0049744 <welements >:   0x00250023 0x00290027 0x00330031 0x00370035
0x 049754 <belements >:   0x50403020 0x90807060
```

Two-dimensional arrays

In C, when nested array of arrays are used, each row is stored contiguously in memory (*row-major* format), and the address of an element can be calculated by the following formula (size of row is the number of columns in a row):

```
address of element[row][col] =
    base address of array +
    (row * size of row * size of element) +
    (col * size of element)
```

-or-

```
base address of array +
(row*size of row + col)*size of element
```

In C, to define a 4x4 array of integers:

```
int twodarr[4][4] = {{0x1, 0x2, 0x3, 0x4},
                    {0x5, 0x6, 0x7, 0x8},
                    {0x9, 0x10,0x11,0x12},
                    {0x13,0x14,0x15,0x16}};
```

The equivalent in X86 is:

```
.data
twodarr: .long 0x1, 0x2, 0x3, 0x4
         .long 0x5, 0x6, 0x7, 0x8
         .long 0x9, 0x10,0x11,0x12
         .long 0x13,0x14,0x15,0x16
```

Either would be displayed using *gdb* as:

```
0x80497a0 <twodarr >:      0x00000001 0x00000002 0x00000003 0x00000004
0x80497b0 <twodarr+16>:    0x00000005 0x00000006 0x00000007 0x00000008
0x80497c0 <twodarr+32>:    0x00000009 0x00000010 0x00000011 0x00000012
0x80497d0 <twodarr+48>:    0x00000013 0x00000014 0x00000015 0x00000016
```