Writing X86 Code Directly

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

```assembly
.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

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
 .data
    total: .quad 0 // 8 byte value with initial value 0
    fstr1: .string "Sum = %d\n"
    fstr2: .string "Total = %d\n"

.text
 .globl main

main:
    lea (%rsi, %rdi, 1), %eax
    add %eax, total
    ret

sum:
    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
```
```c
#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;
}
```
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,

\[
\text{address of element in array} = \text{base address} + \text{element size} \times \text{index}
\]

If the size of the element is limited to 1, 2, 4, or 8 bytes, what is another more efficient way to accomplish the multiplication?

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

```c
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:

```assembly
.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, ... 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
0x049754 <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):

$$\text{address of element[row][col]} = \text{base address of array} + (\text{row} \times (\text{size of row}) \times \text{size of element}) + (\text{col} \times \text{size of element})$$

- or -

$$\text{base address of array} + \text{row} \times (\text{size of row}) + \text{col} \times \text{size of element}$$

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

```c
int twodarr[4][4] = {{0x1, 0x2, 0x3, 0x4},
                     {0x5, 0x6, 0x7, 0x8},
                     {0x9, 0xa, 0xb, 0xc},
                     {0xd, 0xe, 0xf, 0x0}};
```

The equivalent in X86 is:

```assembly
.data
twodarr: .long 0x1, 0x2, 0x3, 0x4
          .long 0x5, 0x6, 0x7, 0x8
          .long 0x9, 0xa, 0xb, 0xc
          .long 0xd, 0xe, 0xf, 0x0
```

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
```