**Labs 8: ELF-Introduction with Code**

This lab may be done either solo or in pairs.

In the previous lab, you learned to investigate and change ELF files using hexedit, and other command-line tools. In this lab, you will continue to manipulate ELF files, this time using your own code (written in C).

We will parse the ELF file and extract useful information from it. In particular, we will access the data in the section header table, and in the symbol table. We will also learn to use the mmap system call.

**Important**

This lab is written for 32bit machines. Some of the computers in the labs already run on a 64bit OS (use*uname -a* to see if the linux OS is 64bit or not). 32bit and 64bit machines have different instruction sets and different memory layout. Make sure to include the *-m32* flag when you compile files, and to use the Elf32 data structures (and not the Elf64 ones).

In order to know if an executable file is compiled for 64bit or 32bit platform, you can use readelf, or the *file* command-line tool (for example: file /bin/ls).

**Useful Tips**

You will no longer be using *hexedit* to process the file and strings to find the information; nevertheless, in some cases you may still want to use these tools for debugging purposes. In order to take advantage of these tools and make your tasks easier, you should:

* Print debugging messages: in particular the offsets of the various items, as you discover them from the headers.
* Use *hexedit* and *readelf* to compare the information you are looking for, especially if you run into unknown problems. *hexedit* is great if you know the exact location of the item you are looking for.
* Note that while the object files you will be processing will be linked using *ld*, and will, in most cases, use direct system calls in order to make the ELF file simpler, there is no reason why the programs you write need use this interface. You are allowed to use the standard library when building your own C programs.
* In order to preserve your sanity, even if the code you MANIPULATE may be without stdlib, we advise that for your OWN CODE you DO use the C standard library!
* In order to keep sane in the following lab as well, **understand** what you are doing and **keep track** of that and of your code, as you will be using them in a future lab.

**Lab 8 Tasks**

**Deliverables**  
You must use only the mmap system call to read/write data into your ELF files from this point onwards.

**Task 0**

This task is about learning to use the mmap system call. Read about the mmap system call (man mmap).

Write a program that uses the mmap to examine the header of a 32bit ELF file (include and use the structures in elf.h). The program is first activated as:

myELF

The program then uses a menu similar to lab 7, with available operations, as follows:

Choose action:

0-Toggle Debug Mode

1-Examine ELF File

2-Quit

Note that the menu should use the same technique as in labs 2 and 7, i.e. an array of structures of available options. Toggle Debug Mode is as in Lab 7. Quit should unmap and close any mapped or open files, and "exit normally". Examine ELF Files queries the user for an ELF file name to be used and examined henceforth. All file input should be read using the mmap system call. You are NOT ALLOWED to use read, or fread.

To make your life easier throughout the lab, map the entire file with one mmap call.

In Examine ELF File, after getting the file name, you should close any currently open file (indicated by global variable Currentfd) open the file for reading, and then print the following:

1. Bytes 1,2,3 of the magic number (in ASCII)
2. Entry point (in hexadecimal)

Check using *readelf* that your data is correct.

Once you verified your output, extend *examine* to print the following information from the header:

1. Bytes 1,2,3 of the magic number (in ASCII). Henceforth, you should check that the number is consistent with an ELF file, and refuse to continue if it is not.
2. The data encoding scheme of the object file.
3. Entry point (hexadecimal address).
4. The file offset in which the section header table resides.
5. The number of section header entries.
6. The size of each section header entry.
7. The file offset in which the program header table resides.
8. The number of program header entries.
9. The size of each program header entry.

The above information should be printed in the above exact order (Print it as nicely as *readelf* does). If invoked on an ELF file, examine should initialize a global file descriptor variable Currentfd for this file, and leave the file open. When invoked on a non-ELF file, or the file cannot be opened or mapped at all, you should print an error message, unmap the file (if already mapped) close the file (if already open), and set Currentfd to -1 to indicate no valid file. You probably also should use a global map\_start variable to indicate the memory location of the mapped file.

**Task 1 - Sections**

Extend your myELF program from Task 0 to allow printing of all the Section names in an 32bit ELF file (like readelf -S). That is, modify the menu to add a "Print Section Names" option:

Choose action:

0-Toggle Debug Mode

1-Examine ELF File

2-Print Section Names

3-Quit

Print Section Names should visit all section headers in the section header table, and for each one print its index, name, address, offset, size in bytes, and type number. Note that this is done for the file currently mapped, so if current fd is invalid, just print an error message and return.

The format should be:

[index] section\_name section\_address section\_offset section\_size section\_type

[index] section\_name section\_address section\_offset section\_size section\_type

[index] section\_name section\_address section\_offset section\_size section\_type

....

Verify your output is correct by comparing it to the output of *readelf*. In debug mode you should also print the value of the important indices and offsets, such as shstrndx and the section name offsets.

You can test your code on the following file: a.out.

**Hints**  
Global information about the ELF file is in the ELF header, including location and size of important tables. The size and name of the sections appear in the section header table. Recall that the actual name **strings** are stored in an appropriate **section** (.shstrtab for section names), and not in the section header!

**Task 2 - Symbols**

Extend your myELF program from task 1 to support an option that displays information on all the symbol names in a 32bit ELF file. Your menu should now be:

Choose action:

0-Toggle Debug Mode

1-Examine ELF File

2-Print Section Names

3-Print Symbols

4-Quit

The new Print Symbols option should visit all the symbols in the current ELF file (if none, print an error message and return). For each symbol, print its index number, its name and the name of the section in which it is defined. (similar to readelf -s). Format should be:

[index] value section\_index section\_name symbol\_name

[index] value section\_index section\_name symbol\_name

[index] value section\_index section\_name symbol\_name

...

Verify your output is correct by comparing it to the output of *readelf*. In debug mode you should first print the size of each symbol table, the number of sybmols therein, and any other useful information.

**Task 3 - Relocations**

**Task 3a: Relocation Table(s) - raw format**

You should extend myELF to support this feature:

Choose action:

0-Toggle Debug Mode

1-Examine ELF File

2-Print Section Names

3-Print Symbols

4-Relocation Tables

5-Quit

Print the content of all fields of all relocation tables entries, in hexadecimal format.  
This is similar to what readelf -r prints, except this feature prints the raw table data (i.e. without fetching symbol name strings). Note that there is a number 4-Link Check. You can do not need to implement that here. Such stubs are known as place holders for future expansion (have a function there that does nothing, or quits).

**Hints**  
To get the relocation table you should look for section of type 'SHT\_REL' and use the offset field. Every entry in this table is of type 'Elf32\_Rel', which has the fields offset and info. Using the macro 'ELF32\_R\_SYM' on the info field gives you the raw data for the symbol (which is an index of the symbol in the .dynsym table where you can find its name and value). Using the 'ELF32\_R\_TYPE' macro on the info field gives you the type of this relocation entry.

For example, using ntsc from lab 7 (readelf -r ntsc):

Offset Info

00001ed4 00000008

00001ed8 00000008

00001ff8 00000008

00002004 00000008

**Task 3b: Relocation Table(s) - semantic format**

You should extend myELF to support this feature:

Choose action:

0-Toggle Debug Mode

1-Examine ELF File

2-Print Section Names

3-Print Symbols

4-Relocation Tables

5-Quit

Now that you have accessed and printed the relocation table, add a printout that displays the entries with the correct semantics, that is, indicate relocation type, symbol used for relocation, etc. The **output should be similar to that generated by readelf -r (relocation type should be printed as a number. There's no need to translate it to a string)**.

To get the relation information regarding values, you need to first get the symbol's index (using ELF32\_R\_SYM on the info field of the relocation entry). You use that to index into the '.dynsym' talbe and get the symbol entry. The value is stored in that table. The name of the symbol is extracted from the '.dynstr' table similarly to what you did in task 2. For example, using ntsc from lab 7 (readelf -r ntsc):

Relocation section '.rel.dyn' at offset 0x340 contains 8 entries:

Offset Info Type Sym.Value Sym. Name

00001ed4 00000008 8

00001ed8 00000008 8

00001ff8 00000008 8

00002004 00000008 8

00001fec 00000106 6 00000000 \_ITM\_deregisterTMClone

00001ff0 00000306 6 00000000 \_\_cxa\_finalize@GLIBC\_2.1.3

00001ff4 00000406 6 00000000 \_\_gmon\_start\_\_

00001ffc 00000706 6 00000000 \_ITM\_registerTMCloneTa

Relocation section '.rel.plt' at offset 0x380 contains 3 entries:

Offset Info Type Sym.Value Sym. Name

00001fe0 00000207 7 00000000 printf@GLIBC\_2.0

00001fe4 00000507 7 00000000 exit@GLIBC\_2.0

00001fe8 00000607 7 00000000 \_\_libc\_start\_main@GLIBC\_2.0

**Deliverables:**

Tasks 1, and 2 must be completed during the regular lab. Task 3 may be done in a completion lab, but only if you run out of time during the regular lab. The deliverables must be submitted until the end of the lab session.  
You must submit source files for tasks 1, 2 and task 3 and a makefile that compiles them. The source files must be named task1.c task2.c, task3.c, and makefile.