

实验8——静态链接、动态链接、动态加载实验

1.实验内容

了解并掌握静态链接、动态链接和动态加载的相关知识。

通过实际链接实践，更深入了解静态链接、动态链接和动态加载这三者之间的区别和联系。

- The static library is loaded memory at start time, and always reside in memory during a program runs to the end.
- The dynamic library is loaded memory at run time when a program needs.
- The suffix of a static library file is .a extension.
- The suffix of a dynamic library file is .so or .sa extension.

2.实验代码

- lib.h

```
1 void bill(char*);  
2 void fred(int);
```

- bill.c

```
1 #include<stdio.h>  
2  
3 void bill(char* arg)  
4 {  
5     printf("bill:you passed %s\n", arg);  
6 }
```

- fred.c

```
1 #include<stdio.h>  
2  
3 void fred(int arg)  
4 {  
5     printf("fred:you passed %d\n", arg);  
6 }
```

- slmain.c

```
1 #include<stdlib.h>  
2 #include"lib.h"  
3  
4 int main()  
5 {  
6     bill("Hello world");  
7     exit(0);  
8 }
```

- dmain.c

```
1 #include<stdlib.h>
2 #include"lib.h"
3
4 int main()
5 {
6     bill("Hello World");
7     exit(0);
8 }
```

3.实验步骤

3.1静态链接

1. 使用gcc -c命令编译bill.c、fred.c、slmain.c文件，获取可共享的.o文件；

```
wys@wys-VirtualBox:~/桌面/lab08/8.1$ ls
bill.c fred.c lib.h slmain.c
wys@wys-VirtualBox:~/桌面/lab08/8.1$ gcc -c bill.c fred.c slmain.c
wys@wys-VirtualBox:~/桌面/lab08/8.1$ ls
bill.c bill.o fred.c fred.o lib.h slmain.c slmain.o
wys@wys-VirtualBox:~/桌面/lab08/8.1$
```

2. 使用gcc -o命令静态链接，生成可执行文件slmain

```
wys@wys-VirtualBox:~/桌面/lab08/8.1$ gcc -o slmain slmain.o bill.o
wys@wys-VirtualBox:~/桌面/lab08/8.1$ ls
bill.c bill.o fred.c fred.o lib.h slmain slmain.c slmain.o
wys@wys-VirtualBox:~/桌面/lab08/8.1$ ./slmain
bill:you passed Hello World
wys@wys-VirtualBox:~/桌面/lab08/8.1$
```

3.2 静态链接：使用ar工具创建静态库的方式实现静态链接

1. 第一步同3.1第一步
2. 随后，使用ar工具，外加参数crv，将可分享的文件bill.o和fred.o组合成静态库libfoo.a；
3. 使用ranlib工具，建立静态链接库libfoo.a的索引，即建立静态库中函数的目录，方便静态库的链接调用；
4. 最后使用gcc编译指令，链接slmain.o和静态库文件libfoo.a生成可执行文件slmain；

```
wys@wys-VirtualBox:~/桌面/lab08/8.2$ ls
bill.c fred.c lib.h slmain.c
wys@wys-VirtualBox:~/桌面/lab08/8.2$ gcc -c fred.c bill.c slmain.c
wys@wys-VirtualBox:~/桌面/lab08/8.2$ ls
bill.c bill.o fred.c fred.o lib.h slmain.c slmain.o
wys@wys-VirtualBox:~/桌面/lab08/8.2$ ar crv libfoo.a bill.o fred.o
a - bill.o
a - fred.o
wys@wys-VirtualBox:~/桌面/lab08/8.2$ ranlib libfoo.a
wys@wys-VirtualBox:~/桌面/lab08/8.2$ ls
bill.c bill.o fred.c fred.o libfoo.a lib.h slmain.c slmain.o
wys@wys-VirtualBox:~/桌面/lab08/8.2$ gcc -o slmain slmain.o libfoo.a
wys@wys-VirtualBox:~/桌面/lab08/8.2$ ./slmain
bill:you passed Hello World
wys@wys-VirtualBox:~/桌面/lab08/8.2$ ls
bill.c bill.o fred.c fred.o libfoo.a lib.h slmain slmain.c slmain.o
wys@wys-VirtualBox:~/桌面/lab08/8.2$
```

3.3 动态链接

1. 使用gcc命令gcc -c -fPIC xxx.c生成位置无关的两个.o文件，并且使用gcc -shared -o xxx.so xxx.o命令利用两个刚刚生成的.o文件创建可共享的动态库libfoo.so；
2. 再次使用gcc编译命令，将dlmain.c编译成可执行文件，其中-lfoo表示链接动态库libfoo.so；

```
wys@wys-VirtualBox:~/桌面/lab08/8.3$ gcc -c -fPIC bill.c fred.c
wys@wys-VirtualBox:~/桌面/lab08/8.3$ ls
bill.c bill.o dlmain.c fred.c fred.o lib.h
wys@wys-VirtualBox:~/桌面/lab08/8.3$ gcc -shared -o libfoo.so bill.o fred.o
wys@wys-VirtualBox:~/桌面/lab08/8.3$ ls
bill.c bill.o dlmain.c fred.c fred.o libfoo.so lib.h
wys@wys-VirtualBox:~/桌面/lab08/8.3$ gcc dlmain.c -o dlmain -L ./ -lfoo
wys@wys-VirtualBox:~/桌面/lab08/8.3$ ls
bill.c bill.o dlmain dlmain.c fred.c fred.o libfoo.so lib.h
wys@wys-VirtualBox:~/桌面/lab08/8.3$ ./dlmain
./dlmain: error while loading shared libraries: libfoo.so: cannot open shared ob
ject file: No such file or directory
wys@wys-VirtualBox:~/桌面/lab08/8.3$
```

3. 完成前两步操作后执行dlmain的可执行文件，发现有无法找到动态链接库的报错，请自行探究原因并修复问题，相关过程需要在实验报告中体现，最终结果如下；

```
wys@wys-VirtualBox:~/桌面/lab08/8.3$ ./dlmain
bill:you passed Hello World
wys@wys-VirtualBox:~/桌面/lab08/8.3$
```

3.4 动态加载

请用动态加载(Dynamic Load)的方式编写一个名为damain.c 程序，可执行文件的名称命名为damain。需要被动态加载的程序名为libtest.c，其内容如下：

```
1 #include<stdio.h>
2
3 void printHello()
4 {
5     printf("After load dynamic library\n");
6     printf("Please enter to continue:");
7     getchar();
8 }
```

动态加载的一般实现步骤

```
1 #include<stdio.h>
2 #include<stdlib.h>
3 #include<dlfcn.h>
4
5 int main(void)
6 {
7     void *plib;
8     typedef void (*FUN)();
9     FUN fun = NULL;
10
11     plib = dlopen("要加载的so库的路径", RTLD_NOW | RTLD_GLOBAL);
12     if(plib == NULL)
13     {
14         printf("error\n");
15         exit(-1);
16     }
```

```

16     }
17     fun = dlsym(plib, "要绑定的函数名");
18     fun();
19     dlclose(plib);
20 }

```

- 相关函数

(1) dlopen, 打开动态库。函数原型void *dlopen (const char *filename, int flag); dlopen用于打开指定名字(filename)的动态库, 并返回操作句柄。

(2) dlsym, 取函数执行地址。函数原型为: void *dlsym(void *handle, char *symbol); dlsym根据动态库操作句柄(handle)与符号(symbol), 返回符号对应的函数的执行代码地址。

(3) dlclose, 关闭动态库。函数原型为: int dlclose (void *handle); dlclose用于关闭指定句柄的动态库, 只有当此动态库的使用计数为0时,才会真正被系统卸载。

- 编译步骤说明

需要像动态链接一样, 先从libtest.c生成libtest.so动态库, 然后经过链接dl动态库编译生成的damain可执行文件会直接调用代码中指定的动态库文件即libtest.so

```

wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ ls
damain.c  libtest.c
wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ gcc libtest.c -shared -fPIC -o libtest.so
wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ ls
damain.c  libtest.c  libtest.so
wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ gcc damain.c -o damain -ldl
wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ ls
damain  damain.c  libtest.c  libtest.so
wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ ./damain
Before load dynamic library
Please enter to continue:
After load dynamic library
Please enter to continue:
After release dynamic library
Please enter to continue:
wys@wys-VirtualBox:~/桌面/lab08/8.4-2$

```

- 实验要求

要求在动态加载动态库的三个状态(加载前、已加载、已卸载)时给出显式的提示和阻塞, 并配合ps -ef|grep xxx和cat maps命令观察在加载的不同阶段内存的变化。

```
wys@wys-VirtualBox: ~/桌面/lab08/8.4-2
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ ./damain
Before load dynamic library
Please enter to continue:

wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ ps -ef|grep damain
wys      13192 12946  0 13:10 pts/0    00:00:00 ./damain
wys      13184 13137  0 13:10 pts/1    00:00:00 grep  --color=auto damain

wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ cd /proc/13182
wys@wys-VirtualBox:/proc/13182$ cat maps
557a72475000-557a72476000 r-xp 00000000 08:01 403591      /home/wys/桌面/lab08/8.4-2/damain
557a72675000-557a72676000 r--p 00000000 08:01 403591      /home/wys/桌面/lab08/8.4-2/damain
557a72676000-557a72677000 rw-p 00001000 08:01 403591      /home/wys/桌面/lab08/8.4-2/damain
557a73d9a000-557a73dbb000 rw-p 00000000 00:00 0          [heap]
7f89442ae000-7f8944495000 r-xp 00000000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f8944495000-7f8944695000 r--p 00000000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f8944695000-7f8944699000 r--p 001e7000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f8944699000-7f894469b000 rw-p 001eb000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f894469b000-7f894469f000 rw-p 00000000 00:00 0
7f894469f000-7f89446a2000 r-xp 00000000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89446a2000-7f89448a1000 r--p 00003000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89448a1000-7f89448a2000 r--p 00002000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89448a2000-7f89448a3000 rw-p 00003000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89448a3000-7f89448b7000 r-xp 00000000 08:01 2496369      /lib/x86_64-linux-gnu/ld-2.27.so
7f89448b7000-7f89448b7000 rw-p 00000000 00:00 0
7f89448b7000-7f8944acd000 r--p 00029000 08:01 2496369      /lib/x86_64-linux-gnu/ld-2.27.so
7f8944acd000-7f8944ace000 rw-p 0002a000 08:01 2496369      /lib/x86_64-linux-gnu/ld-2.27.so
7f8944ace000-7f8944acf000 rw-p 00000000 00:00 0
7ffdea460000-7ffdea481000 rw-p 00000000 00:00 0
7ffdea481000-7ffdea5ab000 r--p 00000000 00:00 0
7ffdea5ab000-7ffdea5ac000 r-xp 00000000 00:00 0
ffffffffff600000-ffffffffff601000 --xp 00000000 00:00 0
wys@wys-VirtualBox:/proc/13182$
```

状态1 加载前

```
wys@wys-VirtualBox: ~/桌面/lab08/8.4-2
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ ./damain
Before load dynamic library
Please enter to continue:
After load dynamic library
Please enter to continue:

wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ ps -ef|grep damain
wys      13182 12946  0 13:10 pts/0    00:00:00 ./damain
wys      13184 13137  0 13:10 pts/1    00:00:00 grep  --color=auto damain

wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ cd /proc/13182
wys@wys-VirtualBox:/proc/13182$ cat maps
557a72475000-557a72476000 r-xp 00000000 08:01 403591      /home/wys/桌面/lab08/8.4-2/damain
557a72675000-557a72676000 r--p 00000000 08:01 403591      /home/wys/桌面/lab08/8.4-2/damain
557a72676000-557a72677000 rw-p 00001000 08:01 403591      /home/wys/桌面/lab08/8.4-2/damain
557a73d9a000-557a73dbb000 rw-p 00000000 00:00 0          [heap]
7f89442ae000-7f8944495000 r-xp 00000000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f8944495000-7f8944695000 r--p 00000000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f8944695000-7f8944699000 r--p 001e7000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f8944699000-7f894469b000 rw-p 001eb000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f894469b000-7f894469f000 rw-p 00000000 00:00 0
7f894469f000-7f89446a2000 r-xp 00000000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89446a2000-7f89448a1000 r--p 00003000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89448a1000-7f89448a2000 r--p 00002000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89448a2000-7f89448a3000 rw-p 00003000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89448a3000-7f89448cc000 r-xp 00000000 08:01 2496369      /lib/x86_64-linux-gnu/ld-2.27.so
7f89448cc000-7f8944ab7000 rw-p 00000000 00:00 0
7f8944ab7000-7f8944acd000 r--p 00029000 08:01 2496369      /lib/x86_64-linux-gnu/ld-2.27.so
7f8944acd000-7f8944ace000 rw-p 0002a000 08:01 2496369      /lib/x86_64-linux-gnu/ld-2.27.so
7f8944ace000-7f8944acf000 rw-p 00000000 00:00 0
7ffdea460000-7ffdea481000 rw-p 00000000 00:00 0
7ffdea481000-7ffdea5ab000 r--p 00000000 00:00 0
7ffdea5ab000-7ffdea5ac000 r-xp 00000000 00:00 0
ffffffffff600000-ffffffffff601000 --xp 00000000 00:00 0
wys@wys-VirtualBox:/proc/13182$ cat maps
557a72475000-557a72476000 r-xp 00000000 08:01 403591      /home/wys/桌面/lab08/8.4-2/damain
557a72675000-557a72676000 r--p 00000000 08:01 403591      /home/wys/桌面/lab08/8.4-2/damain
557a72676000-557a72677000 rw-p 00001000 08:01 403591      /home/wys/桌面/lab08/8.4-2/damain
557a73d9a000-557a73dbb000 rw-p 00000000 00:00 0          [heap]
7f89440ad000-7f89442ac000 r--p 00001000 08:01 403590      /home/wys/桌面/lab08/8.4-2/libtest.so
7f89442ac000-7f89442ad000 r--p 00000000 08:01 403590      /home/wys/桌面/lab08/8.4-2/libtest.so
7f89442ad000-7f89442ae000 rw-p 00001000 08:01 403590      /home/wys/桌面/lab08/8.4-2/libtest.so
7f89442ae000-7f8944495000 r-xp 00000000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f8944495000-7f8944695000 r--p 00000000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f8944695000-7f8944699000 r--p 001e7000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f8944699000-7f894469b000 rw-p 001eb000 08:01 2496397      /lib/x86_64-linux-gnu/libc-2.27.so
7f894469b000-7f894469f000 rw-p 00000000 00:00 0
7f894469f000-7f89446a2000 r-xp 00000000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89446a2000-7f89448a1000 r--p 00003000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89448a1000-7f89448a2000 r--p 00002000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89448a2000-7f89448a3000 rw-p 00003000 08:01 2496420      /lib/x86_64-linux-gnu/libdl-2.27.so
7f89448a3000-7f89448cc000 r-xp 00000000 08:01 2496369      /lib/x86_64-linux-gnu/ld-2.27.so
7f89448cc000-7f8944ab7000 rw-p 00000000 00:00 0
7f8944ab7000-7f8944acd000 r--p 00029000 08:01 2496369      /lib/x86_64-linux-gnu/ld-2.27.so
7f8944acd000-7f8944ace000 rw-p 0002a000 08:01 2496369      /lib/x86_64-linux-gnu/ld-2.27.so
7f8944ace000-7f8944acf000 rw-p 00000000 00:00 0
7ffdea460000-7ffdea481000 rw-p 00000000 00:00 0
7ffdea481000-7ffdea5ab000 r--p 00000000 00:00 0
7ffdea5ab000-7ffdea5ac000 r-xp 00000000 00:00 0
ffffffffff600000-ffffffffff601000 --xp 00000000 00:00 0
wys@wys-VirtualBox:/proc/13182$
```

状态2 已加载

```
wys@wys-VirtualBox: ~/桌面/lab08/8.4-2
文件(F) 编辑(E) 查看(V) 搜索(S) 终端(T) 帮助(H)
wys@wys-VirtualBox:~/桌面/lab08/8.4-2$ ./damain
Before load dynamic library
Please enter to continue:
After load dynamic library
Please enter to continue:
After release dynamic library
Please enter to continue:[]

wys@wys-VirtualBox: /proc/13182$ cat maps
7ffdea460000-7ffdea481000 rw-p 00000000 00:00 0
7ffdea5a8000-7ffdea5ab000 r--p 00000000 00:00 0
7ffdea5ab000-7ffdea5ac000 r-xp 00000000 00:00 0
ffffffffff600000-ffffffffff601000 --xp 00000000 00:00 0
wys@wys-VirtualBox: /proc/13182$ cat maps
557a72475000-557a72476000 r-xp 00000000 08:01 403591
557a72675000-557a72676000 r--p 00000000 08:01 403591
557a72676000-557a72677000 rw-p 00001000 08:01 403591
557a73d9a000-557a73dbb000 rw-p 00000000 00:00 0
7f89440ac000-7f89440ad000 r-xp 00000000 08:01 403590
7f89440ad000-7f89442ac000 ---p 00001000 08:01 403590
7f89442ac000-7f89442ad000 r--p 00000000 08:01 403590
7f89442ad000-7f89442ae000 rw-p 00001000 08:01 403590
7f89442ae000-7f8944495000 r-xp 00000000 08:01 2496397
7f8944495000-7f8944499000 ---p 001e7000 08:01 2496397
7f8944499000-7f8944499000 r--p 001e7000 08:01 2496397
7f8944499000-7f894449b000 rw-p 001eb000 08:01 2496397
7f894449b000-7f894462000 r-xp 00000000 00:00 0
7f894462000-7f89446a2000 r-xp 00000000 08:01 2496420
7f89446a2000-7f89448a1000 ---p 00003000 08:01 2496420
7f89448a1000-7f89448a2000 r--p 00002000 08:01 2496420
7f89448a2000-7f89448a3000 rw-p 00003000 08:01 2496420
7f89448a3000-7f89448ac000 r-xp 00000000 08:01 2496369
7f89448ab2000-7f8944ab7000 rw-p 00000000 00:00 0
7f8944ac000-7f8944acd000 r--p 00029000 08:01 2496369
7f8944acd000-7f8944ace000 rw-p 0002a000 08:01 2496369
7f8944ace000-7f8944acf000 rw-p 00000000 00:00 0
7ffdea460000-7ffdea481000 rw-p 00000000 00:00 0
7ffdea5a8000-7ffdea5ab000 r--p 00000000 00:00 0
7ffdea5ab000-7ffdea5ac000 r-xp 00000000 00:00 0
ffffffffff600000-ffffffffff601000 --xp 00000000 00:00 0
wys@wys-VirtualBox: /proc/13182$ cat maps
557a72475000-557a72476000 r-xp 00000000 08:01 403591
557a72675000-557a72676000 r--p 00000000 08:01 403591
557a72676000-557a72677000 rw-p 00001000 08:01 403591
557a73d9a000-557a73dbb000 rw-p 00000000 00:00 0
7f894442ae000-7f8944495000 r-xp 00000000 08:01 2496397
7f8944495000-7f8944499000 ---p 001e7000 08:01 2496397
7f8944499000-7f8944499000 r--p 001e7000 08:01 2496397
7f8944499000-7f894449b000 rw-p 001eb000 08:01 2496397
7f894449b000-7f894469f000 rw-p 00000000 00:00 0
7f894469f000-7f89446a2000 r-xp 00000000 08:01 2496420
7f89446a2000-7f89448a1000 ---p 00003000 08:01 2496420
7f89448a1000-7f89448a2000 r--p 00002000 08:01 2496420
7f89448a2000-7f89448a3000 rw-p 00003000 08:01 2496420
7f89448a3000-7f89448cc000 r-xp 00000000 08:01 2496369
7f89448ab2000-7f8944ab7000 rw-p 00000000 00:00 0
7f8944ac000-7f8944acd000 r--p 00029000 08:01 2496369
7f8944acd000-7f8944ace000 rw-p 0002a000 08:01 2496369
7f8944ace000-7f8944acf000 rw-p 00000000 00:00 0
7ffdea460000-7ffdea481000 rw-p 00000000 00:00 0
7ffdea5a8000-7ffdea5ab000 r--p 00000000 00:00 0
7ffdea5ab000-7ffdea5ac000 r-xp 00000000 00:00 0
ffffffffff600000-ffffffffff601000 --xp 00000000 00:00 0
wys@wys-VirtualBox: /proc/13182$
```

状态3 已卸载