CS 35L- Software Construction Laboratory

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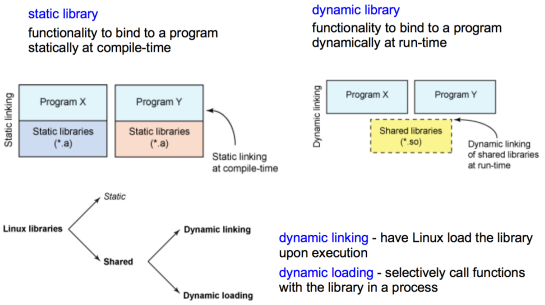
Anatomy of Linux shared libraries



dynamic linking - have Linux load the library upon execution

dynamic loading - selectively call functions with the library in a process

Dynamic Loading

- Let an application load and link libraries itself
  - application can specify a particular library to load, then
  - application can call functions within that library
- Load shared libraries from disk (file) into memory and re-adjust its location
- The Dynamic Loading API

Table 1. The DI API

Function	Description
dlopen	Makes an object file accessible to a program
dlsym	Obtains the address of a symbol within a `dlopen`ed object file
dlerror	Returns a string error of the last error that occurred
dlclose	Closes an object file

src: https://www.ibm.com/developerworks/library/l-dynamic-libraries/

The Dynamic Loading API

- dlopen - makes an object file accessible to a program
  - void *dlopen(const char *file, int mode);
  - RTLD NOW → relocate now; RTLD LAZY → to relocate when needed;
- dlsym - gives resolved address to a symbol within this object
  - void *dlsym(void *restrict handle, const char *restrict name);
  - check char *dlerror(); if an error occurs
- dlerror - returns a string error of the last error that occurred
- dlclose - closes an object file

Dynamic Loading: Example

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

int main(int argc, char* argv[]) {
 int i = 10;
 void (*myfunc)(int *); void *dl_handle;
 char *error;

 dl_handle = dlopen("libmymath.so", RTLD_LAZY);//RTLD_NOW
 if(!dl_handle) {
  printf("dlopen() error - %s\n", dlerror()); return 1;
 }
 //Calling mul5(&i);
 myfunc = dlsym(dl_handle, "mul5"); error = dlerror();
 if(error != NULL) {
  printf("dlsym mul5 error - %s\n", error); return 1;
 }
 myfunc(&i);
  //Calling add1(&i);
  myfunc = dlsym(dl_handle, "add1"); error = dlerror();
  if(error != NULL) {
   printf("dlsym add1 error - %s\n", error); return 1;
  }
  myfunc(&i);
  printf("i = %d\n", i);
  dlclose(dl_handle);
  return 0;
}
```

- Copy the code into main.c
- gcc main.c -o main –ldl
- You need to set the environment variable **LD_LIBRARY_PATH** to include the path that contains libmymath.so

Create static and shared libs in GCC

- mymath.h

```
#ifndef _ MY_MATH_H
#define _ MY_MATH_H
void mul5(int *i);
void add1(int *i);
#endif
```

- mul5.c

```
#include "mymath.h"
void mul5(int *i)
{
  *i *= 5;
}
```

- add1.c

```
#include "mymath.h"
void add1(int *i)
{
  *i += 1;
}
```

- gcc -c mul5.c -o mul5.o
- gcc -c add1.c -o add1.o
- ar -cv libmymath.a mul5.o add1.o → (static lib)
- gcc -shared -fpic -o libmymath.so mul5.o add1.o → (shared lib)

Attributes of Functions

- Used to declare certain things about functions called in your program
  - Help the compiler optimize calls and check code
- Also used to control memory placement, code generation options or call/return conventions within the function being annotated
- Introduced by the **attribute** keyword on a declaration, followed by an attribute specification inside double parentheses

Reference: https://gcc.gnu.org/onlinedocs/gcc-3.1/gcc/Function-Attributes.html

Attributes of Functions

- `__attribute__ ((__constructor__))`
  - Is run when `dlopen()` is called
- `__attribute__ ((__destructor__))`
  - Is run when `dlclose()` is called
- Example:

```
__attribute__ ((__constructor__))
void to_run_before (void) {
    printf("pre_func\n");
}
```

Homework 7

- Divide randall.c into dynamically linked modules and a main program. We don't want resulting executable to load code that it doesn't need (dynamic loading)
- randall.c = randcpuid.c + randlibhw.c + randlibsw.c + randmain.c
  - **randcpuid.c**: contains code that determines whether the current CPU has the RDRAND instruction. Should include randcpuid.h and include interface described by it.
  - **randlibhw.c**: contains the hardware implementation of the random number generator. Should include randlib.h and implement interface described by it.
  - **randlibsw.c**: contains the software implementation of the random number generator. Should include randlib.h and implement interface described by it.
  - **randmain.c**: contains the main program that glues together everything else. Should include randcpuid.h but not randlib.h. Depending on whether the hardware supports the RDRAND instruction, this main program should dynamically load the hardware oriented or software oriented implementation of randlib.

Homework 7

- 3 steps:
  - Build libraries; load libraries; run functions in libraries.
- Stitch the files together via static and dynamic linking to create the program
- **randmain.c** must use *dynamic loading, dynamic linking* to link up with randlibhw.c and randlibsw.c (using randlib.h)
- Write the **randmain.mk** makefile to do the linking

Homework 7

- Additional references: GCC **Flags**
  - -fPIC: compile directive to output position independent code, a characteristic required by shared library
  - -lXXX: Link with "libXXX.so"
    - Without –L to directly specify the path, /usr/lib is used
  - -L: At compile time, find .so file from this path.
  - -Wl, rpath=.: passes options to the linker. –rpath at runtime finds .so from this path
  - -c: Generate objective code from C code.
  - -shared: Produce a shared code that can be linked with other objects to form an executable

Homework 7

- randall.c outputs N random bytes of data

  Look at the code and understand it
  - Helper functions that check if hardware random number generator is available, and if it is, generates number
    - Hw RNG exists if RDRAND instruction exists
    - Uses cpuid to check whether CPU supports RDRAND (30th bit of ECX register is set)
  - Helper functions to generate random numbers using software implementation (/dev/urandom)
  - Main function
    - Checks number of arguments (name of program, N)
    - Converts N to long integer, prints error message otherwise
    - Uses helper functions to generate random number using hw/sw