Московский Авиационный Институт

(Национальный Исследовательский Университет)

Институт №8 “Компьютерные науки и прикладная математика”

Кафедра №806 “Вычислительная математика и программирование”

Лабораторная работа №4 по курсу

«Операционные системы»

Группа: М8О-215Б-23

Студент: Голосов Г.С.

Преподаватель: Миронов Е.С.

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Постановка задачи

Вариант 14.

Требуется создать динамические библиотеки, которые реализуют заданный вариантом функционал. Далее использовать данные библиотеки 2-мя способами:

1. Во время компиляции (на этапе «линковки»/linking)
2. Во время исполнения программы. Библиотеки загружаются в память с помощью интерфейса ОС для работы с динамическими библиотеками

В конечном итоге, в лабораторной работе необходимо получить следующие части:

- Динамические библиотеки, реализующие контракты, которые заданы вариантом;
- Тестовая программа (программа №1), которая используют одну из библиотек, используя информацию полученные на этапе компиляции;
- Тестовая программа (программа №2), которая загружает библиотеки, используя только их относительные пути и контракты.

Провести анализ двух типов использования библиотек.

Пользовательский ввод для обоих программ должен быть организован следующим образом:

1. Если пользователь вводит команду «0», то программа переключает одну реализацию контрактов на другую (необходимо только для программы №2). Можно реализовать лабораторную работу без данной функции, но максимальная оценка в этом случае будет «хорошо»;
2. «1 arg1 arg2 … argN», где после «1» идут аргументы для первой функции, предусмотренной контрактами. После ввода команды происходит вызов первой функции, и на экране появляется результат её выполнения;
3. «2 arg1 arg2 … argM», где после «2» идут аргументы для второй функции, предусмотренной контрактами. После ввода команды происходит вызов второй функции, и на экране появляется результат её выполнения.

Функция 1: Рассчет производной функции cos(x) в точке A с приращением deltaX.
Сигнатура: Float Derivative(float A, float deltaX).
Реализация 1: df(x)/dx = (f(A + deltaX) – f(A))/deltaX.
Реализация 2: df(x)/dx = (f(A + deltaX) – f(A-deltaX))/(2*deltaX).

Функция 2: Перевод числа x из десятичной системы счисления в другую
Сигнатура: Char* translation(long x)
Реализация 1: Другая система счисления двоичная
Реализация 2: Другая система счисления троичная

Общий метод и алгоритм решения

- void* dlopen(const char* filename, int flag); - загружает динамическую библиотеку в память
- int dlclose(void* handle); - выгружает динамическую библиотеку из памяти
- void* dlsym(void* handle, const char* symbol); - получает адрес символа из библиотеки
- char* dlerror(void); - возвращает строку с описанием последней ошибки

Алгоритм решения:

1. Создаем файлы с реализацией функций (по одному на каждую, в итоге 4)
2. Создаем первую программу, которой будем передавать данные библиотеки на этапе компиляции
3. Создаем вторую программу, в которой дополнительно прописываем логику для загрузки и выгрузки динамических библиотек

Prog1

Программа 1 линкуется на этапе компиляции с первой библиотекой (libimpl1.so) и напрямую вызывает функции Derivative и translation из неё. Для подключения функций просто объявляем их перед main. Далее в зависимости от ввода пользователя считаем производную или переводим число в двоичную систему.

Prog2

Программа 2 использует динамическую загрузку библиотек в процессе выполнения. При запуске она загружает libimpl1.so с помощью dlopen.
При вводе команды «0» происходит переключение – закрывается текущая библиотека и загружается другая (libimpl2.so или обратно libimpl1.so).
Функции извлекаются через dlsym и затем вызываются по тому же контракту.

Makefile

С помощью Makefile выполняется сборка и компиляция программы. Для успешной компиляции нужно описать все цели, реквизиты и указать команды. Для компиляции C++ используем компилятор g++. Так как мы берем на себя линковку, то при компиляции нужно использовать флаг -c, чтобы получить объектный файл.

Код программы

Makefile

```
all: prog1 prog2 libimpl1.so libimpl2.so clean

# Program 1 (линковка на этапе компиляции)
prog1: prog1.o libimpl1.so
    g++ -o prog1 prog1.o -L. -limpl1 -Wl,-rpath,.

prog1.o: prog1.cpp
    g++ -c prog1.cpp

# Program 2 (динамическая загрузка)
prog2: prog2.o
    g++ -o prog2 prog2.o -ldl

prog2.o: prog2.cpp
    g++ -c prog2.cpp

# Combined Library for Implementation 1
libimpl1.so: math_lib1.o convert_lib1.o
    g++ -shared -o libimpl1.so math_lib1.o convert_lib1.o

math_lib1.o: math_lib1.cpp
    g++ -c -fPIC math_lib1.cpp

convert_lib1.o: convert_lib1.cpp
    g++ -c -fPIC convert_lib1.cpp

# Combined Library for Implementation 2
libimpl2.so: math_lib2.o convert_lib2.o
    g++ -shared -o libimpl2.so math_lib2.o convert_lib2.o

math_lib2.o: math_lib2.cpp
    g++ -c -fPIC math_lib2.cpp

convert_lib2.o: convert_lib2.cpp
    g++ -c -fPIC convert_lib2.cpp

# Clean: удаление объектных файлов
clean:
    rm -f *.o
```

math_lib1.cpp

```
#include <cmath>

extern "C" float Derivative(float A, float deltaX) {
    return (cos(A + deltaX) - cos(A)) / deltaX;
}
```

math_lib2.cpp

```
#include <cmath>

extern "C" float Derivative(float A, float deltaX) {
    return (cos(A + deltaX) - cos(A - deltaX)) / (2 * deltaX);
}
```

convert_lib1.cpp

```
#include <cstdlib>

extern "C" char* translation(long x) {
    if (x == 0) {
        char* result = new char[2];
        result[0] = '0';
        result[1] = '\0';
        return result;
    }

    bool isNegative = (x < 0);
    if (isNegative) {
        x = -x;
    }

    // Максимальное количество цифр для двоичного представления 64-битного числа – 64
    const int MAX_DIGITS = 65; // 64 цифры + 1 для '\0'
    char* temp = new char[MAX_DIGITS];
    int pos = 0;

    // Преобразуем число в двоичное представление (цифры записываются в обратном порядке)
    while (x > 0) {
        temp[pos++] = (x % 2) + '0';
        x /= 2;
    }

    // Вычисляем итоговый размер строки: если число отрицательное, добавляем 1 символ для знака
    int resultSize = pos + (isNegative ? 2 : 1);
    char* result = new char[resultSize];

    int j = 0;
    if (isNegative) {
        result[j++] = '-';
    }

    // Переворачиваем цифры из temp
    for (int i = pos - 1; i >= 0; i--) {
        result[j++] = temp[i];
    }
    result[j] = '\0';

    delete[] temp;
    return result;
}
```

_lib2.cpp

```
#include <cstdlib>

extern "C" char* translation(long x) {
    if (x == 0) {
        char* result = new char[2];
        result[0] = '0';
        result[1] = '\0';
        return result;
    }

    bool isNegative = (x < 0);
    if (isNegative) {
        x = -x;
    }

    // Для системы счисления с основанием 3 достаточно 42 цифр
    const int MAX_DIGITS = 42;
    char* temp = new char[MAX_DIGITS];
    int pos = 0;

    while (x > 0) {
        temp[pos++] = (x % 3) + '0';
        x /= 3;
    }

    int resultSize = pos + (isNegative ? 2 : 1);
    char* result = new char[resultSize];

    int j = 0;
    if (isNegative) {
        result[j++] = '-';
    }

    for (int i = pos - 1; i >= 0; i--) {
        result[j++] = temp[i];
    }
    result[j] = '\0';

    delete[] temp;
    return result;
}
```

Prog1.cpp

```
#include <iostream>

extern "C" float Derivative(float A, float deltaX);
extern "C" char* translation(long x);

int main() {
    int prog;
    while (true) {
        std::cout << "Input program code:\n 1 -> Calculate derivative\n 2 -> Translation\n-1 -> Exit\n";
        std::cin >> prog;
```

```
        switch (prog) {
            case 1: {
                std::cout << "Enter A and deltaX: ";
                float A, deltaX;
                std::cin >> A >> deltaX;
                std::cout << "Calculated derivative: " << Derivative(A, deltaX) << "\n\n";
                break;
            }
            case 2: {
                long x;
                std::cout << "Enter x: ";
                std::cin >> x;
                std::cout << "Translated number: " << translation(x) << "\n\n";
                break;
            }
            case -1:
                std::cout << "Exit\n";
                return 0;
            default:
                std::cout << "Invalid input. Try again.\n";
        }
    }
}
```

Prog2.cpp

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

int main() {
    int prog = 1;
    int real = 1;
    void *lib = nullptr;

    typedef float (*DerivativeFunc)(float, float);
    typedef char* (*TranslationFunc)(long);

    DerivativeFunc Derivative;
    TranslationFunc translation;

    // Начальная загрузка объединённой библиотеки для реализации 1
    lib = dlopen("./libimpl1.so", RTLD_LAZY);
    if (!lib) {
        std::cerr << "Error loading initial library: " << dlerror() << std::endl;
        return 1;
    }
    std::cout << "Library is loaded\n";

    Derivative = (DerivativeFunc) dlsym(lib, "Derivative");
    translation = (TranslationFunc) dlsym(lib, "translation");
    if (!Derivative || !translation) {
        std::cerr << "Failed to load symbols: " << dlerror() << std::endl;
        dlclose(lib);
        return 1;
    }
```

```
    while (true) {
        std::cout << "Input program code:\n 0 -> Library switch\n 1 -> Calculate derivative\n 2 ->
Translation\n-1 -> Exit\n";
        std::cin >> prog;
        switch (prog) {
            case 0:
                dlclose(lib); // Закрываем текущую библиотеку
                if (real == 1) {
                    lib = dlopen("./libimpl2.so", RTLD_LAZY);
                    real = 2;
                } else {
                    lib = dlopen("./libimpl1.so", RTLD_LAZY);
                    real = 1;
                }
                if (!lib) {
                    std::cerr << "Error loading library: " << dlerror() << std::endl;
                    return 1;
                }
                std::cout << "Library switched successfully!\n";
                // Перезагружаем символы
                Derivative = (DerivativeFunc) dlsym(lib, "Derivative");
                translation = (TranslationFunc) dlsym(lib, "translation");
                if (!Derivative || !translation) {
                    std::cerr << "Failed to load symbols: " << dlerror() << std::endl;
                    dlclose(lib);
                    return 1;
                }
                break;
            case 1: {
                float A, deltaX;
                std::cout << "Enter A and deltaX: ";
                std::cin >> A >> deltaX;
                if (real == 1)
                    std::cout << "Calculating derivative using first method\n";
                else
                    std::cout << "Calculating derivative using second method\n";
                std::cout << "Derivative: " << Derivative(A, deltaX) << "\n\n";
                break;
            }
            case 2: {
                long x;
                std::cout << "Enter x: ";
                std::cin >> x;
                if (real == 1)
                    std::cout << "Translating to binary\n";
                else
                    std::cout << "Translating to ternary\n";
                std::cout << "Result is: " << translation(x) << "\n\n";
                break;
            }
            case -1:
                std::cout << "Exit\n";
                dlclose(lib);
                return 0;
```

```
            default:
                std::cout << "Invalid input. Try again.\n";
        }
    }
}
```

Протокол работы программы

Prog1

```
tobiklosj@LAPTOP-C3C2PI9E:~/labs_OS/lab4$ ./prog1
Input program code:
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
1
Enter A and deltaX: 0.5 0.01
Calculated derivative: -0.483805

Input program code:
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
2
Enter x: 129
Translated number: 10000001
```

Prog2

```
Library is loaded
Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
1
Enter A and deltaX: 0.5 0.01
Calculating derivative using first method
Derivative: -0.483805

Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
2
Enter x: 129
Translating to binary
Result is: 10000001

Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
```

```
0
Library switched successfully!
Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
1
Enter A and deltaX: 0.5 0.01
Calculating derivative using second method
Derivative: -0.479417

Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
2
Enter x: 156
Translating to ternary
Result is: 12210

Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
0
Library switched successfully!
Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
2
Enter x: 10
Translating to binary
Result is: 1010

Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
2
Enter x: 0
Translating to binary
Result is: 0


Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
```

```
Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
2
Enter x: -1231
Translating to binary
Result is: -10011001111
0
Library switched successfully!
Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
2
Enter x: -15
Translating to ternary
Result is: -120
```

Strace

Prog1

```
tobiklosj@LAPTOP-C3C2PI9E:~/labs_OS/lab4$ strace -f ./prog1
execve("./prog1", ["./prog1"], 0x7ffd79485008 /* 26 vars */) = 0
brk(NULL)                               = 0x560f0c038000
arch_prctl(0x3001 /* ARCH_??? */, 0x7ffc74d0dee0) = -1 EINVAL (Invalid argument)
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7f2d2122c000
access("/etc/ld.so.preload", R_OK)      = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "./glibc-hwcaps/x86-64-v3/libimpl1.so", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
openat(AT_FDCWD, "./glibc-hwcaps/x86-64-v2/libimpl1.so", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
openat(AT_FDCWD, "./tls/haswell/x86_64/libimpl1.so", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No
such file or directory)
openat(AT_FDCWD, "./tls/haswell/libimpl1.so", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file
or directory)
openat(AT_FDCWD, "./tls/x86_64/libimpl1.so", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file
or directory)
openat(AT_FDCWD, "./tls/libimpl1.so", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or
directory)
openat(AT_FDCWD, "./haswell/x86_64/libimpl1.so", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No
such file or directory)
openat(AT_FDCWD, "./haswell/libimpl1.so", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or
directory)
openat(AT_FDCWD, "./x86_64/libimpl1.so", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or
directory)
openat(AT_FDCWD, "./libimpl1.so", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0755, st_size=15672, ...}, AT_EMPTY_PATH) = 0
getcwd("/home/tobiklosj/labs_OS/lab4", 128) = 29
mmap(NULL, 16448, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2d21227000
```

```
mmap(0x7f2d21228000, 4096, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1000) = 0x7f2d21228000
mmap(0x7f2d21229000, 4096, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x2000) = 0x7f2d21229000
mmap(0x7f2d2122a000, 8192, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x2000) = 0x7f2d2122a000
close(3)                                = 0
openat(AT_FDCWD, "./glibc-hwcaps/x86-64-v3/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "./glibc-hwcaps/x86-64-v2/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = -1
ENOENT (No such file or directory)
openat(AT_FDCWD, "./tls/haswell/x86_64/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
openat(AT_FDCWD, "./tls/haswell/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such
file or directory)
openat(AT_FDCWD, "./tls/x86_64/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such
file or directory)
openat(AT_FDCWD, "./tls/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or
directory)
openat(AT_FDCWD, "./haswell/x86_64/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No
such file or directory)
openat(AT_FDCWD, "./haswell/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file
or directory)
openat(AT_FDCWD, "./x86_64/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file
or directory)
openat(AT_FDCWD, "./libstdc++.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or
directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=37419, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 37419, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f2d2121d000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=2260296, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 2275520, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2d20ff1000
mprotect(0x7f2d2108b000, 1576960, PROT_NONE) = 0
mmap(0x7f2d2108b000, 1118208, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x9a000) = 0x7f2d2108b000
mmap(0x7f2d2119c000, 454656, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1ab000) = 0x7f2d2119c000
mmap(0x7f2d2120c000, 57344, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x21a000) = 0x7f2d2120c000
mmap(0x7f2d2121a000, 10432, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7f2d2121a000
close(3)                                = 0
openat(AT_FDCWD, "./glibc-hwcaps/x86-64-v3/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
openat(AT_FDCWD, "./glibc-hwcaps/x86-64-v2/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT
(No such file or directory)
openat(AT_FDCWD, "./tls/haswell/x86_64/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No
such file or directory)
openat(AT_FDCWD, "./tls/haswell/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or
directory)
openat(AT_FDCWD, "./tls/x86_64/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or
directory)
```

```
openat(AT_FDCWD, "./tls/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or
directory)
openat(AT_FDCWD, "./haswell/x86_64/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such
file or directory)
openat(AT_FDCWD, "./haswell/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or
directory)
openat(AT_FDCWD, "./x86_64/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or
directory)
openat(AT_FDCWD, "./libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0P\237\2\0\0\0\0\0"..., 832) = 832
pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784
pread64(3, "\4\0\0\0 \0\0\0\5\0\0\0GNU\0\2\0\0\300\4\0\0\0\3\0\0\0\0\0\0\0"..., 48, 848) = 48
pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0\315A\vq\17\17\tLh2\355\331Y1\0m"..., 68, 896) = 68
newfstatat(3, "", {st_mode=S_IFREG|0755, st_size=2220400, ...}, AT_EMPTY_PATH) = 0
pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0"..., 784, 64) = 784
mmap(NULL, 2264656, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2d20dc8000
mprotect(0x7f2d20df0000, 2023424, PROT_NONE) = 0
mmap(0x7f2d20df0000, 1658880, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x28000) = 0x7f2d20df0000
mmap(0x7f2d20f85000, 360448, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1bd000) = 0x7f2d20f85000
mmap(0x7f2d20fde000, 24576, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x215000) = 0x7f2d20fde000
mmap(0x7f2d20fe4000, 52816, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7f2d20fe4000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libm.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=940560, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 942344, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2d20ce1000
mmap(0x7f2d20cef000, 507904, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0xe000) = 0x7f2d20cef000
mmap(0x7f2d20d6b000, 372736, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x8a000) = 0x7f2d20d6b000
mmap(0x7f2d20dc6000, 8192, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0xe4000) = 0x7f2d20dc6000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libgcc_s.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=125488, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 127720, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7f2d20cc1000
mmap(0x7f2d20cc4000, 94208, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x3000) = 0x7f2d20cc4000
mmap(0x7f2d20cdb000, 16384, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1a000) = 0x7f2d20cdb000
mmap(0x7f2d20cdf000, 8192, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1d000) = 0x7f2d20cdf000
close(3)                                = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7f2d20cbf000
mmap(NULL, 12288, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7f2d20cbc000
arch_prctl(ARCH_SET_FS, 0x7f2d20cbc740) = 0
set_tid_address(0x7f2d20cbca10)         = 20821
```

```
set_robust_list(0x7f2d20cbca20, 24)     = 0
rseq(0x7f2d20cbd0e0, 0x20, 0, 0x53053053) = 0
mprotect(0x7f2d20fde000, 16384, PROT_READ) = 0
mprotect(0x7f2d20cdf000, 4096, PROT_READ) = 0
mprotect(0x7f2d20dc6000, 4096, PROT_READ) = 0
mprotect(0x7f2d2120c000, 45056, PROT_READ) = 0
mprotect(0x7f2d2122a000, 4096, PROT_READ) = 0
mprotect(0x560edeaa5000, 4096, PROT_READ) = 0
mprotect(0x7f2d21266000, 8192, PROT_READ) = 0
prlimit64(0, RLIMIT_STACK, NULL, {rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}) = 0
munmap(0x7f2d2121d000, 37419)           = 0
getrandom("\xe4\xf1\x31\x56\x21\x94\x8d\x30", 8, GRND_NONBLOCK) = 8
brk(NULL)                               = 0x560f0c038000
brk(0x560f0c059000)                     = 0x560f0c059000
futex(0x7f2d2121a77c, FUTEX_WAKE_PRIVATE, 2147483647) = 0
newfstatat(1, "", {st_mode=S_IFCHR|0620, st_rdev=makedev(0x88, 0x2), ...}, AT_EMPTY_PATH) = 0
write(1, "Input program code:\n", 20Input program code:
)   = 20
write(1, " 1 -> Calculate derivative\n", 27 1 -> Calculate derivative
) = 27
write(1, " 2 -> Translation\n", 18 2 -> Translation
)     = 18
write(1, "-1 -> Exit\n", 11-1 -> Exit
)          = 11
newfstatat(0, "", {st_mode=S_IFCHR|0620, st_rdev=makedev(0x88, 0x2), ...}, AT_EMPTY_PATH) = 0
read(0, 2
"2\n", 1024)                    = 2
write(1, "Enter x: ", 9Enter x: )               = 9
read(0, 12
"12\n", 1024)                   = 3
write(1, "Translated number: 1100\n\n", 25Translated number: 1100

) = 25
write(1, "Input program code:\n 1 -> Calcul"..., 76Input program code:
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
) = 76
read(0, 1
"1\n", 1024)                    = 2
write(1, "Enter A and deltaX: ", 20Enter A and deltaX: )    = 20
read(0, 0.5 0.01
"0.5 0.01\n", 1024)             = 9
write(1, "Calculated derivative: -0.483805"..., 34Calculated derivative: -0.483805

) = 34
write(1, "Input program code:\n 1 -> Calcul"..., 76Input program code:
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
) = 76
read(0, -1
"-1\n", 1024)                   = 3
write(1, "Exit\n", 5Exit
)                 = 5
```

```
lseek(0, -1, SEEK_CUR)                  = -1 ESPIPE (Illegal seek)
exit_group(0)                           = ?
+++ exited with 0 +++
```

Prog2

```
tobiklosj@LAPTOP-C3C2PI9E:~/labs_OS/lab4$ strace -f ./prog2
execve("./prog2", ["./prog2"], 0x7ffc8148fe58 /* 26 vars */) = 0
brk(NULL)                               = 0x564118386000
arch_prctl(0x3001 /* ARCH_??? */, 0x7fffd58f9d10) = -1 EINVAL (Invalid argument)
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7fa7ddd19000
access("/etc/ld.so.preload", R_OK)      = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=37419, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 37419, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7fa7ddd0f000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libstdc++.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=2260296, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 2275520, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fa7ddae3000
mprotect(0x7fa7ddb7d000, 1576960, PROT_NONE) = 0
mmap(0x7fa7ddb7d000, 1118208, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x9a000) = 0x7fa7ddb7d000
mmap(0x7fa7ddc8e000, 454656, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1ab000) = 0x7fa7ddc8e000
mmap(0x7fa7ddcfe000, 57344, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x21a000) = 0x7fa7ddcfe000
mmap(0x7fa7ddd0c000, 10432, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7fa7ddd0c000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0P\237\2\0\0\0\0\0"..., 832) = 832
pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0"..., 784, 64) = 784
pread64(3, "\4\0\0\0 \0\0\0\5\0\0\0GNU\0\2\0\0\300\4\0\0\0\3\0\0\0\0\0\0"..., 48, 848) = 48
pread64(3, "\4\0\0\0\24\0\0\0\3\0\0\0GNU\0\315A\vq\17\17\tLh2\355\331Y1\0m"..., 68, 896) = 68
newfstatat(3, "", {st_mode=S_IFREG|0755, st_size=2220400, ...}, AT_EMPTY_PATH) = 0
pread64(3, "\6\0\0\0\4\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0\0@\0\0\0\0\0\0"..., 784, 64) = 784
mmap(NULL, 2264656, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fa7dd8ba000
mprotect(0x7fa7dd8e2000, 2023424, PROT_NONE) = 0
mmap(0x7fa7dd8e2000, 1658880, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x28000) = 0x7fa7dd8e2000
mmap(0x7fa7dda77000, 360448, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1bd000) = 0x7fa7dda77000
mmap(0x7fa7ddad0000, 24576, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x215000) = 0x7fa7ddad0000
mmap(0x7fa7ddad6000, 52816, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7fa7ddad6000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libm.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=940560, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 942344, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fa7dd7d3000
mmap(0x7fa7dd7e1000, 507904, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0xe000) = 0x7fa7dd7e1000
```

```
mmap(0x7fa7dd85d000, 372736, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x8a000) = 0x7fa7dd85d000
mmap(0x7fa7dd8b8000, 8192, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0xe4000) = 0x7fa7dd8b8000
close(3)                                = 0
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libgcc_s.so.1", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0644, st_size=125488, ...}, AT_EMPTY_PATH) = 0
mmap(NULL, 127720, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fa7dd7b3000
mmap(0x7fa7dd7b6000, 94208, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x3000) = 0x7fa7dd7b6000
mmap(0x7fa7dd7cd000, 16384, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1a000) = 0x7fa7dd7cd000
mmap(0x7fa7dd7d1000, 8192, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1d000) = 0x7fa7dd7d1000
close(3)                                = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7fa7dd7b1000
arch_prctl(ARCH_SET_FS, 0x7fa7dd7b23c0) = 0
set_tid_address(0x7fa7dd7b2690)         = 21845
set_robust_list(0x7fa7dd7b26a0, 24)     = 0
rseq(0x7fa7dd7b2d60, 0x20, 0, 0x53053053) = 0
mprotect(0x7fa7ddad0000, 16384, PROT_READ) = 0
mprotect(0x7fa7dd7d1000, 4096, PROT_READ) = 0
mprotect(0x7fa7dd8b8000, 4096, PROT_READ) = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7fa7dd7af000
mprotect(0x7fa7ddcfe000, 45056, PROT_READ) = 0
mprotect(0x5640de46e000, 4096, PROT_READ) = 0
mprotect(0x7fa7ddd53000, 8192, PROT_READ) = 0
prlimit64(0, RLIMIT_STACK, NULL, {rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}) = 0
munmap(0x7fa7ddd0f000, 37419)           = 0
getrandom("\x26\x10\xd0\x95\x94\xf5\x50\xd8", 8, GRND_NONBLOCK) = 8
brk(NULL)                               = 0x564118386000
brk(0x5641183a7000)                     = 0x5641183a7000
futex(0x7fa7ddd0c77c, FUTEX_WAKE_PRIVATE, 2147483647) = 0
openat(AT_FDCWD, "./libimpl1.so", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0755, st_size=15672, ...}, AT_EMPTY_PATH) = 0
getcwd("/home/tobiklosj/labs_OS/lab4", 128) = 29
mmap(NULL, 16448, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fa7ddd14000
mmap(0x7fa7ddd15000, 4096, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1000) = 0x7fa7ddd15000
mmap(0x7fa7ddd16000, 4096, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x2000) = 0x7fa7ddd16000
mmap(0x7fa7ddd17000, 8192, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x2000) = 0x7fa7ddd17000
close(3)                                = 0
mprotect(0x7fa7ddd17000, 4096, PROT_READ) = 0
newfstatat(1, "", {st_mode=S_IFCHR|0620, st_rdev=makedev(0x88, 0x2), ...}, AT_EMPTY_PATH) = 0
write(1, "Library is loaded\n", 18Library is loaded
)     = 18
write(1, "Input program code:\n 0 -> Librar"..., 97Input program code:
 0 -> Library switch
 1 -> Calculate derivative
```

```
 2 -> Translation
-1 -> Exit
) = 97
newfstatat(0, "", {st_mode=S_IFCHR|0620, st_rdev=makedev(0x88, 0x2), ...}, AT_EMPTY_PATH) = 0
read(0, 1
"1\n", 1024)                    = 2
write(1, "Enter A and deltaX: ", 20Enter A and deltaX: )    = 20
read(0, 0.5 0.01
"0.5 0.01\n", 1024)             = 9
write(1, "Calculating derivative using fir"..., 42Calculating derivative using first method
) = 42
write(1, "Derivative: -0.483805\n\n", 23Derivative: -0.483805

) = 23
write(1, "Input program code:\n 0 -> Librar"..., 97Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
) = 97
read(0, 2
"2\n", 1024)                    = 2
write(1, "Enter x: ", 9Enter x: )               = 9
read(0, 123
"123\n", 1024)                  = 4
write(1, "Translating to binary\n", 22Translating to binary
) = 22
write(1, "Result is: 1111011\n\n", 20Result is: 1111011

)  = 20
write(1, "Input program code:\n 0 -> Librar"..., 97Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
) = 97
read(0, 0
"0\n", 1024)                    = 2
munmap(0x7fa7ddd14000, 16448)           = 0
openat(AT_FDCWD, "./libimpl2.so", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\0\0\0\0\0\0\0\0"..., 832) = 832
newfstatat(3, "", {st_mode=S_IFREG|0755, st_size=15672, ...}, AT_EMPTY_PATH) = 0
getcwd("/home/tobiklosj/labs_OS/lab4", 128) = 29
mmap(NULL, 16448, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7fa7ddd14000
mmap(0x7fa7ddd15000, 4096, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1000) = 0x7fa7ddd15000
mmap(0x7fa7ddd16000, 4096, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x2000) = 0x7fa7ddd16000
mmap(0x7fa7ddd17000, 8192, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x2000) = 0x7fa7ddd17000
close(3)                                = 0
mprotect(0x7fa7ddd17000, 4096, PROT_READ) = 0
write(1, "Library switched successfully!\n", 31Library switched successfully!
) = 31
write(1, "Input program code:\n 0 -> Librar"..., 97Input program code:
```

```
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
) = 97
read(0, 2
"2\n", 1024)                    = 2
write(1, "Enter x: ", 9Enter x: )               = 9
read(0, 42
"42\n", 1024)                   = 3
write(1, "Translating to ternary\n", 23Translating to ternary
) = 23
write(1, "Result is: 1120\n\n", 17Result is: 1120

)     = 17
write(1, "Input program code:\n 0 -> Librar"..., 97Input program code:
 0 -> Library switch
 1 -> Calculate derivative
 2 -> Translation
-1 -> Exit
) = 97
read(0, -1
"-1\n", 1024)                   = 3
write(1, "Exit\n", 5Exit
)                 = 5
munmap(0x7fa7ddd14000, 16448)           = 0
lseek(0, -1, SEEK_CUR)                  = -1 ESPIPE (Illegal seek)
exit_group(0)                           = ?
+++ exited with 0 +++
```

Вывод

В ходе лабораторной работы была изучена работа с динамическими библиотеками и двумя вариантами их загрузки: динамической в процесее выполнения программы и статической при компиляции и линковке