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»

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Оценка: _____

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Постановка задачи

Вариант 32.

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:

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:

- 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»;
- “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 ее выполнения;

- “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 ее выполнения.

6. Расчет значения числа e (основание натурального логарифма):

Сигнатура функции: float e(int x);

- Реализация №1: $(1 + 1 / x)^x$

- Реализация №2: Сумма ряда по n от 0 до x, где элементы ряда равны: (1 / (n!))

8. Перевод числа x из десятичной системы счисления в другую:

Сигнатура функции: char *convert(int x);

- Реализация №1: Перевод в двоичную

- Реализация №2: Перевод в троичную

Общий метод и алгоритм решения

Использованные системные вызовы:

- **void *dlopen(const char *filename, int flags)** – загружает в память и открывает динамическую библиотеку.
- **void *dlsym(void *handle, const char *symbol)** – возвращает адрес функции или переменной из загруженной библиотеки.

- **int dlclose(void *handle)** – выгружает из памяти ранее загруженную динамическую библиотеку.

Алгоритм решения:

Разрабатываются две динамические библиотеки с идентичным интерфейсом, но разными алгоритмами расчета числа e (предел или ряд Тейлора) и перевода систем счисления (двоичная или троичная). Первая программа линкуется с библиотекой на этапе компиляции и вызывает функции напрямую, а вторая использует API dlopen/dlsym для явной загрузки .so-файла в память во время исполнения. Это позволяет второй программе менять реализацию на лету: по команде пользователя она выгружает текущую библиотеку через dlclose, загружает альтернативную и обновляет указатели на функции для выполнения новых расчетов.

Код программы

libs.h

```
#ifndef LIBS_H

#define LIBS_H


float e(int x);

char *convert(int x);


#endif
```

lib1.c

```
#include <math.h>

#include <stdlib.h>

#include <string.h>

#include <unistd.h>

#include <stdio.h>


#include "../include/libs.h"


void reverse(char *str) {

    int n = strlen(str);

    for (int i = 0; i < n/2; ++i) {
```

```
        char temp = str[n - i - 1];
        str[n - i - 1] = str[i];
        str[i] = temp;
    }
}

float e(int x) {
    if (x == 0) return 1.0;
    return powf(1.0f + 1.0f / (float)x, (float)x);
}

char *convert(int x) {
    char *buffer = (char *)malloc(65 * sizeof(char));
    if (!buffer) return NULL;

    if (x == 0) {
        strcpy(buffer, "0");
        return buffer;
    }

    int index = 0;
    int is_negative = 0;

    if (x < 0) {
        is_negative = 1;
        x = -x;
    }

    while (x > 0) {
        buffer[index++] = (x % 2) + '0';
```

```
        x /= 2;
    }

    if (is_negative) {
        buffer[index++] = '-';
    }

    buffer[index] = '\0';
    reverse(buffer);

    return buffer;
}
```

lib2.c

```
#include <math.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include <stdio.h>

#include "../include/libs.h"

void reverse(char *str) {
    int n = strlen(str);
    for (int i = 0; i < n/2; ++i) {
        char temp = str[n - i - 1];
        str[n - i - 1] = str[i];
        str[i] = temp;
    }
}
```

```
double factorial(int n) {
    double res = 1.0;
    for (int i = 2; i <= n; ++i) res *= i;
    return res;
}

float e(int x) {
    float sum = 0.0f;
    for (int n = 0; n <= x; ++n) {
        sum += 1.0f / (float)factorial(n);
    }
    return sum;
}

char *convert(int x) {
    char *result = (char*)malloc(sizeof(char) * 65);
    if (!result) return NULL;

    int index = 0;
    if (x == 0) {
        strcpy(result, "0");
        return result;
    }

    int is_negative = 0;
    if (x < 0) {
        is_negative = 1;
        x = -x;
    }
```

```
    while (x != 0) {
        result[index++] = (x % 3) + '0';
        x /= 3;
    }

    if (is_negative) {
        result[index++] = '-';
    }
    result[index] = '\0';
    reverse(result);
    return result;
}
```

prog1.c

```
#include <unistd.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>

#include "../include/libs.h"

#define BUFFER_SIZE 4096

void command_1() {
    char* arg1 = strtok(NULL, " \t\n");

    int len = 0;
    char buffer[BUFFER_SIZE];
```

```
    if (arg1) {
        int x = atoi(arg1);
        float res = e(x);
        len = snprintf(buffer, BUFFER_SIZE, "e(%d) result: %.6f\n", x, res);
        write(STDOUT_FILENO, buffer, len);
    } else {
        const char msg[] = "error: missing argument for command 1\n";
        write(STDERR_FILENO, msg, sizeof(msg)-1);
    }
}

void command_2() {
    char* arg1 = strtok(NULL, " \t\n");

    int len = 0;
    char buffer[BUFFER_SIZE];

    if (arg1) {
        int x = atoi(arg1);
        char* res = convert(x);

        if (res) {
            len = snprintf(buffer, BUFFER_SIZE, "convert(%d) result: %s\n", x, res);
            write(STDOUT_FILENO, buffer, len);
            free(res);
        } else {
            const char msg[] = "error: memory alloc\n";
            write(STDERR_FILENO, msg, sizeof(msg)-1);
        }
    } else {
```

```
        const char msg[] = "error: missing argument for command 2\n";
        write(STDERR_FILENO, msg, sizeof(msg)-1);
    }
}

int main() {
    {
        const char* message = "static prog\ncommands: 1 - e_func; 2 - convert; ctrl d to exit\n> ";
        write(STDOUT_FILENO, message, strlen(message));
    }

    int bytes_read = 0;
    char buffer[BUFFER_SIZE];

    while((bytes_read = read(STDIN_FILENO, buffer, BUFFER_SIZE - 1)) > 0) {
        buffer[bytes_read] = 0;

        char* token = strtok(buffer, " \t\n");
        if (!token) {
            write(STDOUT_FILENO, "> ", 2);
            continue;
        }

        int cmd = atoi(token);
        switch (cmd) {
            case 1:
                command_1();
                break;
            case 2:
                command_2();
```

```
            break;
        default:
            {
                const char msg[] = "unknown command\n";
                write(STDOUT_FILENO, msg, sizeof(msg)-1);
            }
            break;
    }

    write(STDOUT_FILENO, "> ", 2);
  }

  write(STDOUT_FILENO, "\n", 1);
  return 0;
}
```

prog2.c

```
#include <stddef.h>
#include <unistd.h>
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <dlfcn.h>

#include "../include/libs.h"

#define BUFFER_SIZE 4096

typedef float (*e_func_t)(int);
typedef char* (*convert_func_t)(int);
```

```
enum ErrorCode {
    OK = 0,
    ER_DLOPEN = -1,
    ER_DLSYM = -2,
};

enum CurrentLib {
    FIRST = 0,
    SECOND = 1,
};

enum ErrorCode command_0(const char** LIB_NAMES, void** library, int* current_lib,
e_func_t* e_func, convert_func_t* convert_func) {
    char buffer[BUFFER_SIZE];

    if (*library) {
        dlclose(*library);
        *library = NULL;
    }

    *current_lib = (*current_lib == FIRST) ? SECOND : FIRST;

    *library = dlopen(LIB_NAMES[*current_lib], RTLD_NOW);

    if (!(*library)) {
        int len = snprintf(buffer, BUFFER_SIZE, "error switching libs: %s\n", dlerror());
        write(STDERR_FILENO, buffer, len);
        return ER_DLOPEN;
    }
```

```
    dlerror();

    *e_func = (e_func_t)dlsym(*library, "e");
    if (!*e_func) {
        int len = snprintf(buffer, BUFFER_SIZE, "error finding 'e': %s\n", dlerror());
        write(STDERR_FILENO, buffer, len);
        return ER_DLSYM;
    }

    *convert_func = (convert_func_t)dlsym(*library, "convert");
    if (!*convert_func) {
        int len = snprintf(buffer, BUFFER_SIZE, "error finding 'convert': %s\n", dlerror());
        write(STDERR_FILENO, buffer, len);
        return ER_DLSYM;
    }

    int len = snprintf(buffer, BUFFER_SIZE, "switched to library: %s\n",
LIB_NAMES[*current_lib]);
    write(STDOUT_FILENO, buffer, len);

    return OK;
}

void command_1(e_func_t e_func) {
    if (!e_func) return;

    char* arg1 = strtok(NULL, " \t\n");
    char buffer[BUFFER_SIZE];
    int len = 0;
```

```
    if (arg1) {
        int x = atoi(arg1);
        float res = e_func(x);
        len = snprintf(buffer, BUFFER_SIZE, "e(%d) result: %.6f\n", x, res);
        write(STDOUT_FILENO, buffer, len);
    } else {
        const char msg[] = "error: missing argument for command 1\n";
        write(STDERR_FILENO, msg, sizeof(msg)-1);
    }
}

void command_2(convert_func_t convert_func) {
    if (!convert_func) return;

    char* arg1 = strtok(NULL, " \t\n");
    char buffer[BUFFER_SIZE];
    int len = 0;

    if (arg1) {
        int x = atoi(arg1);
        char* res = convert_func(x);

        if (res) {
            len = snprintf(buffer, BUFFER_SIZE, "convert(%d) result: %s\n", x, res);
            write(STDOUT_FILENO, buffer, len);
            free(res);
        } else {
            const char msg[] = "error: memory alloc\n";
            write(STDERR_FILENO, msg, sizeof(msg)-1);
        }
```

```
    } else {
        const char msg[] = "error: missing argument for command 2\n";
        write(STDERR_FILENO, msg, sizeof(msg)-1);
    }
}

int main() {
    const char* LIB_NAMES[] = {"./lib1.so", "./lib2.so"};
    int current_lib = FIRST;

    e_func_t e_func = NULL;
    convert_func_t convert_func = NULL;
    void* library = NULL;
    char buffer[BUFFER_SIZE];

    library = dlopen(LIB_NAMES[current_lib], RTLD_NOW);
    if (!library) {
        int len = snprintf(buffer, BUFFER_SIZE, "error loading initial lib: %s\n", dlerror());
        write(STDERR_FILENO, buffer, len);
        return ER_DLOPEN;
    }

    e_func = (e_func_t)dlsym(library, "e");
    convert_func = (convert_func_t)dlsym(library, "convert");

    if (!e_func || !convert_func) {
        const char msg[] = "error: functions not found in library\n";
        write(STDERR_FILENO, msg, sizeof(msg)-1);
        return ER_DLSYM;
    }
```

```
{
    const char *msg = "dynamic program.\ncommands: 0 - switch; 1 - e_func; 2 - convert\n> ";
    write(STDOUT_FILENO, msg, strlen(msg));
}

int bytes_read;
while ((bytes_read = read(STDIN_FILENO, buffer, BUFFER_SIZE - 1)) > 0) {
    buffer[bytes_read] = '\0';
    char *token = strtok(buffer, " \t\n");
    if (!token) {
        write(STDOUT_FILENO, "> ", 2);
        continue;
    }

    int cmd = atoi(token);
    switch (cmd) {
        case 0:
            if (command_0(LIB_NAMES, &library, &current_lib, &e_func, &convert_func) != OK)
                return ER_DLOPEN;
            break;
        case 1:
            command_1(e_func);
            break;
        case 2:
            command_2(convert_func);
            break;
        default:
            {
                const char msg[] = "unknown command\n";
```

```
                write(STDOUT_FILENO, msg, sizeof(msg)-1);
            }
            break;
        }

        write(STDOUT_FILENO, "> ", 2);
    }

    if (library) dlclose(library);
    write(STDOUT_FILENO, "\n", 1);
    return OK;
}
```

Протокол работы программы

Тесты:

```
user@MacBook-Pro-Egor-2 laba4_proj % make clean
make
rm -f *.so prog1 prog2
gcc -Wall -Wextra -Iinclude -fPIC -shared  -o lib1.so src/lib1.c -lm
gcc -Wall -Wextra -Iinclude -fPIC -shared  -o lib2.so src/lib2.c -lm
gcc -Wall -Wextra -Iinclude -o prog1 src/prog1.c ./lib1.so -lm
gcc -Wall -Wextra -Iinclude -o prog2 src/prog2.c -ldl
user@MacBook-Pro-Egor-2 laba4_proj % ./prog1
./prog2

static prog
commands: 1 - e_func; 2 - convert; ctrl d to exit
> 1 5
e(5) result: 2.488321
> 2 2
convert(2) result: 10
> 0
unknown command
> qwerty
unknown command
> ^D
dynamic program.
commands: 0 - switch; 1 - e_func; 2 - convert
> 0
switched to library: ./lib2.so
> 1
error: missing argument for command 1
> 1 5
e(5) result: 2.716667
> 2 4
convert(4) result: 11
> 2 2
convert(2) result: 2
```

Strace:

tru@tru:~/Downloads$ strace -f ./prog2

execve("./prog2", ["./prog2"], 0xffffb49ad78 /* 76 vars */) = 0

brk(NULL) = 0xaaab09423000

mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffff9fae9000

faccessat(AT_FDCWD, "/etc/ld.so.preload", R_OK) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/tls/aarch64/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/tls/aarch64/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/tls/aarch64/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/tls/aarch64", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/tls/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/tls/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/tls/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/tls", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/aarch64/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/aarch64/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/aarch64/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/aarch64", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib", {st_mode=S_IFDIR|0775, st_size=12288, ...}, 0) = 0

openat(AT_FDCWD, "/opt/ros/noetic/lib/tls/aarch64/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/opt/ros/noetic/lib/tls/aarch64/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/opt/ros/noetic/lib/tls/aarch64/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/opt/ros/noetic/lib/tls/aarch64", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/opt/ros/noetic/lib/tls/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/opt/ros/noetic/lib/tls/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/opt/ros/noetic/lib/tls/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/opt/ros/noetic/lib/tls", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/opt/ros/noetic/lib/aarch64/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/opt/ros/noetic/lib/aarch64/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/opt/ros/noetic/lib/aarch64/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/opt/ros/noetic/lib/aarch64", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/opt/ros/noetic/lib/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/opt/ros/noetic/lib/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/opt/ros/noetic/lib/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/opt/ros/noetic/lib", {st_mode=S_IFDIR|0755, st_size=12288, ...}, 0) = 0

openat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/tls/aarch64/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/tls/aarch64/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/tls/aarch64/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/tls/aarch64", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/tls/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/tls/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/tls/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/tls", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/aarch64/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/aarch64/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/aarch64/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/aarch64", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/home/tru/catkin_ws/install/lib/mavlink_sitl_gazebo/plugins", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/tls/aarch64/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/tls/aarch64/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/tls/aarch64/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/tls/aarch64", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/tls/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/tls/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/tls/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/tls", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/aarch64/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/aarch64/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/aarch64/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/aarch64", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/atomics", 0xffffe9ea8be0, 0) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

newfstatat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins", {st_mode=S_IFDIR|0755, st_size=4096, ...}, 0) = 0

openat(AT_FDCWD, "tls/aarch64/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "tls/aarch64/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "tls/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "tls/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "aarch64/atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "aarch64/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "atomics/libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "libdl.so.2", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3

fstat(3, {st_mode=S_IFREG|0644, st_size=247550, ...}) = 0

mmap(NULL, 247550, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff9fa80000

close(3) = 0

openat(AT_FDCWD, "/lib/aarch64-linux-gnu/libdl.so.2", O_RDONLY|O_CLOEXEC) = 3

read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0P\17\0\0\0\0\0"..., 832) = 832

fstat(3, {st_mode=S_IFREG|0644, st_size=14560, ...}) = 0

mmap(NULL, 78080, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0xffff9fa6c000

mprotect(0xffff9fa6f000, 61440, PROT_NONE) = 0

mmap(0xffff9fa7e000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x2000) = 0xffff9fa7e000

close(3) = 0

openat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/opt/ros/noetic/lib/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "tls/aarch64/atomics/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "tls/aarch64/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "tls/atomics/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, "aarch64/atomics/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "aarch64/libc.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "atomics/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/aarch64-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\267\0\1\0\0\0`\17\2\0\0\0\0"..., 832) = 832

fstat(3, {st_mode=S_IFREG|0755, st_size=1450832, ...}) = 0

mmap(NULL, 1519552, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0xffff9f8f9000

mprotect(0xffff9fa54000, 61440, PROT_NONE) = 0

mmap(0xffff9fa63000, 24576, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x15a000) = 0xffff9fa63000

mmap(0xffff9fa69000, 12224, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0xffff9fa69000

close(3) = 0

mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0xffff9fae7000

mprotect(0xffff9fa63000, 16384, PROT_READ) = 0

mprotect(0xffff9fa7e000, 4096, PROT_READ) = 0

mprotect(0xaaaad7231000, 4096, PROT_READ) = 0

mprotect(0xffff9faee000, 4096, PROT_READ) = 0

munmap(0xffff9fa80000, 247550) = 0

brk(NULL) = 0xaaab09423000

brk(0xaaab09444000) = 0xaaab09444000

openat(AT_FDCWD, "./lib1.so", O_RDONLY|O_CLOEXEC) = 3

read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0000\6\0\0\0\0\0"..., 832) = 832

fstat(3, {st_mode=S_IFREG|0775, st_size=8360, ...}) = 0

getcwd("/home/tru/Downloads", 128) = 20

mmap(NULL, 69696, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0xffff9faab000

mprotect(0xffff9faac000, 61440, PROT_NONE) = 0

mmap(0xffff9fabb000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0) = 0xffff9fabb000

close(3) = 0

openat(AT_FDCWD, "/home/tru/catkin_ws/devel/lib/libm.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/opt/ros/noetic/lib/libm.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "/usr/share/gazebo-11/../../lib/aarch64-linux-gnu/gazebo-11/plugins/libm.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "tls/aarch64/atomics/libm.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "tls/aarch64/libm.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "tls/atomics/libm.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "tls/libm.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "aarch64/atomics/libm.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "aarch64/libm.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "atomics/libm.so.6", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)

openat(AT_FDCWD, "libm.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

fstat(3, {st_mode=S_IFREG|0644, st_size=247550, ...}) = 0

mmap(NULL, 247550, PROT_READ, MAP_PRIVATE, 3, 0) = 0xffff9f8bc000

close(3) = 0

openat(AT_FDCWD, "/lib/aarch64-linux-gnu/libm.so.6", O_RDONLY|O_CLOEXEC) = 3

read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0\360\272\0\0\0\0\0\0"..., 832) = 832

fstat(3, {st_mode=S_IFREG|0644, st_size=633832, ...}) = 0

mmap(NULL, 696440, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0xffff9f811000

mprotect(0xffff9f8aa000, 65536, PROT_NONE) = 0

mmap(0xffff9f8ba000, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x99000) = 0xffff9f8ba000

close(3) = 0

mprotect(0xffff9f8ba000, 4096, PROT_READ) = 0

mprotect(0xffff9fabb000, 4096, PROT_READ) = 0

munmap(0xffff9f8bc000, 247550) = 0

write(1, "dynamic program.\ncommands: 0 - s"..., 65dynamic program.

commands: 0 - switch; 1 - e_func; 2 - convert

>) = 65

read(0, 1 4

"1 4\n", 4095) = 4

write(1, "e(4) result: 2.441406\n", 22e(4) result: 2.441406

) = 22

write(1, "> ", 2>) = 2

```
read(0, 0
"0\n", 4095)                    = 2
munmap(0xffff9faab000, 69696)           = 0
munmap(0xffff9f811000, 696440)          = 0
openat(AT_FDCWD, "./lib2.so", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\0\0\0\0\0\0\0\0\0\3\0\267\0\1\0\0\0\0\6\0\0\0\0\0\0"..., 832) = 832
fstat(3, {st_mode=S_IFREG|0775, st_size=8352, ...}) = 0
getcwd("/home/tru/Downloads", 128)      = 20
mmap(NULL, 69696, PROT_READ|PROT_EXEC, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) =
0xffff9faab000
mprotect(0xffff9faac000, 61440, PROT_NONE) = 0
mmap(0xffff9fabb000, 8192, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0) = 0xffff9fabb000
close(3)                        = 0
mprotect(0xffff9fabb000, 4096, PROT_READ) = 0
write(1, "switched to library: ./lib2.so\n", 31switched to library: ./lib2.so
) = 31
write(1, "> ", 2> )                     = 2
read(0, 1 3
"1 3\n", 4095)                  = 4
write(1, "e(3) result: 2.666667\n", 22e(3) result: 2.666667
) = 22
write(1, "> ", 2> )                     = 2
read(0, "", 4095)                       = 0
munmap(0xffff9faab000, 69696)           = 0
write(1, "\n", 1
)                       = 1
exit_group(0)                           = ?
+++ exited with 0 +++
tru@tru:~/Downloads$
```

Вывод

В ходе лабораторной работы я научился создавать динамические библиотеки, создавать программы, использующие динамические библиотеки. Также я научился создавать статические библиотеки и использовать их при компиляции программы.