

**Gebze Technical University
Department of Computer
Engineering
CSE344 - Spring 2024
Homework 4
AHMET ALPER UZUNTEPE
1901042669**

```
alper@alper-VirtualBox:~/hwtest/put_your_codes_here
```

```
Copied /home/alper/Masaüstü/hw4test/testdir/pixmaps/tb_shell.xpm to /home/alper/Masaüstü/hwtest/tocopy/pixmaps/tb_shell.xpm
Copied /home/alper/Masaüstü/hw4test/testdir/pixmaps/tb_find_next.xpm to /home/alper/Masaüstü/hwtest/tocopy/pixmaps/tb_find_next.xpm
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Copied /home/alper/Masaüstü/hw4test/testdir/.github/ISSUE_TEMPLATE/bug_report.md to /home/alper/Masaüstü/hw4test/tocopy/.github/ISSUE_TEMPLATE/bug_report.md
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///////////////////////////////////////////////////////////////////////////STATISTIC///////////////////////////////////////////////////////////////////////////
Execution time: 144673 ms
Number of files copied: 3116
Number of directories copied: 151
Total bytes copied: 73520554
Buffer size: 10
Number of worker threads: 10
==44693=
==44693= HEAP SUMMARY:
==44693=     in use at exit: 0 bytes in 0 blocks
==44693=   total heap usage: 6,699 allocs, 6,699 frees, 5,415,425 bytes allocated
==44693= All heap blocks were freed -- no leaks are possible
==44693= For lists of detected and suppressed errors, rerun with: -s
==44693= ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 0 from 0)
alper@alper-VirtualBox:~/Masaüstü/hwtest/put_your_codes_here$ 
```

Overview

I wrote this code for implementation and functionality of a multithreaded file copy program in C. The program leverages POSIX threads (pthreads) to manage concurrent file copying from a source directory to a destination directory. Key components of the program include the use of a circular buffer to manage file information, condition variables for synchronizing access to the buffer, and barriers for coordinating the start of worker threads.

Initialization

The program begins by initializing necessary data structures and variables. This includes parsing command-line arguments to set the buffer size, number of worker threads, and paths for the source and destination directories.

Buffer Structure

A circular buffer is used to hold information about files to be copied. The buffer is implemented using a structure `buffer_t`, which includes:

- An array buffer to store file information.
- Indices front and rear to manage the head and tail of the buffer.
- A count variable count to track the number of items in the buffer.
- Mutex mutex and condition variables `cond_full` and `cond_empty` for synchronization.

Thread Functions

The program employs two types of threads: a manager thread and multiple worker threads.

Manager Thread

The manager thread is responsible for:

- Reading directory contents.
- Enqueuing file information into the buffer.
- Handling directories recursively by creating corresponding directories in the destination.

The manager thread sets a flag `done_flag` upon completing directory processing, signaling to worker threads that no more files will be enqueued.

Worker Threads

Worker threads perform the following tasks:

- Wait at a barrier to ensure all threads start simultaneously.
- Dequeue file information from the buffer.
- Copy data from source to destination files using read and write operations.
- Signal completion and handle errors if encountered.

Synchronization Mechanisms

Condition Variable Usage

cond_full

- **Wait (Manager Thread):**

```
while (buffer.count == buffer_size) //wait if buffer is full
    pthread_cond_wait(&buffer.cond_full, &buffer.mutex);
```

- The manager thread waits on cond_full when it tries to add a file to a full buffer. This ensures that the manager thread blocks until there is space available in the buffer.
- The pthread_cond_wait function releases the mutex and waits for the cond_full condition variable to be signaled. Once signaled, it re-acquires the mutex and proceeds.

- **Signal (Worker Thread):**

```
//signal that the buffer is not full
pthread_cond_signal(&buffer.cond_full);
```

- Worker threads signal cond_full when they remove a file from the buffer, indicating that there is now space available for the manager to add new files.
- This function wakes up one of the threads waiting on the cond_full condition variable, allowing the manager thread to proceed and enqueue more files.

cond_empty

- **Wait (Worker Threads):**

```
//wait if buffer is empty
while (buffer.count == 0)
    pthread_cond_wait(&buffer.cond_empty, &buffer.mutex);
```

- Worker threads wait on cond_empty when they try to remove a file from an empty buffer. This ensures that worker threads block until there is a file available in the buffer.
- Similar to cond_full, pthread_cond_wait releases the mutex and waits for the cond_empty condition variable to be signaled. Once signaled, it re-acquires the mutex and proceeds.

- **Signal (Manager Thread):**

```
// signal that the buffer is not empty
pthread_cond_signal(&buffer.cond_empty);
```

- The manager thread signals cond_empty when it adds a file to the buffer, indicating that there is now a file available for the workers to process.
- This function wakes up one of the threads waiting on the cond_empty condition variable, allowing a worker thread to proceed and dequeue a file.

- ❖ **Mutex and Condition Variables:** The condition variables work in conjunction with a mutex (buffer.mutex). This mutex ensures that only one thread can access the buffer at a time, preventing race conditions.
- ❖ **Blocking and Waking Up Threads:** The condition variables are used to block threads when the buffer is in an undesirable state (full or empty) and to wake up threads when the state changes to a desirable one (space available or file available).
- ❖ **Synchronization:** This mechanism allows the manager and worker threads to work efficiently together without busy-waiting, leading to better performance and resource utilization.

Barrier Usage

- **Initialization:**

```
pthread_barrier_init(&barrier, NULL, num_workers + 1); //initialize the barrier
```

 - The barrier is initialized in the main function with a count of num_workers + 1, accounting for the manager thread and all worker threads.
- **Start Synchronization:**

```
pthread_barrier_wait(&barrier); //wait at the barrier in the main thread
```

 - At the beginning of both manager and worker functions, threads wait at the barrier, ensuring they all start their operations together.
- **End Synchronization:**

```
pthread_barrier_wait(&barrier); //wait at the barrier
```

 - After processing the directory, the manager thread signals the completion of its task by waiting at the barrier, which is now only waited upon by the manager.
 - This ensures that worker threads are aware that no more files will be added to the buffer once the manager has completed its task.
- **Barrier Destruction:**

```
pthread_barrier_destroy(&barrier); //destroy the barrier
```

 - Finally, the barrier is destroyed in the main function after all threads have finished their execution.
- ❖ The barrier usage ensures proper synchronization between the manager and worker threads. The start barrier ensures that all threads begin processing simultaneously, while the end barrier ensures that worker threads are aware of the completion of directory processing by the manager. This coordination helps prevent race conditions and ensures efficient parallel processing of file copying tasks.

CODE EXPLANATION

- **Structures and Global Variables**
 - **file_info_t** Structure holds information about each file to be copied.

```
typedef struct { //structure to hold info about each file
    char *src_path; //source file path
    char *dest_path; //destination file path
    int src_fd; //source file descriptor
    int dest_fd; //destination file descriptor
} file_info_t;
```

- **buffer_t** Structure represents a circular buffer used to store **file_info_t** items.

```
typedef struct { // circular buffer structure for holding files to copied
    file_info_t *buffer; // dynamic array to store file info
    int front, rear; // indices for front and rear of the buffer
    int count; // count of items in the buffer
    pthread_mutex_t mutex; // mutex for synchronizing access to the buffer
    pthread_cond_t cond_full; // buffer is full
    pthread_cond_t cond_empty; // buffer is empty
} buffer_t;
```

- **Global Variables**

```
buffer_t buffer; //buffer instance
int buffer_size, num_workers; //buffer size and number of worker threads
char *src_dir, *dest_dir; //source and destination directory paths
int done_flag = 0; // flag to indicate directory processing is done
pthread_barrier_t barrier; // barrier for synchronizing worker threads
int num_files_copied = 0; //track of number of files copied
int num_directories_copied = 0; //track of number of directories copied
size_t total_bytes_copied = 0; //track of total bytes copied
pthread_mutex_t stats_mutex = PTHREAD_MUTEX_INITIALIZER; // mutex for synchronizing statistics update
```

- **buffer**: An instance of **buffer_t** used to hold file information during the copying process.
- **buffer_size**: An integer indicating the maximum size of the buffer.
- **num_workers**: An integer indicating the number of worker threads.
- **src_dir**: A pointer to a string representing the source directory path.
- **dest_dir**: A pointer to a string representing the destination directory path.
- **done_flag**: An integer flag used to indicate when the manager thread has finished processing the directory.
- **barrier**: A pthread barrier used to synchronize the start of the worker threads.
- **num_files_copied, num_directories_copied, total_bytes_copied**: They are using for tracking and calculating STATISTICS.
- **stats_mutex** :A Mutex for synchronizing statistic updates.

- Buffer Initialization

```
void init_buffer() { //func for initialize buffer
    buffer.front = buffer.rear = 0;
    buffer.count = 0;
    pthread_mutex_init(&buffer.mutex, NULL);
    pthread_cond_init(&buffer.cond_full, NULL);
    pthread_cond_init(&buffer.cond_empty, NULL);
    buffer.buffer = malloc(buffer_size * sizeof(file_info_t)); //allocate memory for buffer
    if (buffer.buffer == NULL)
        error_handler("Memory allocation failed");
}
```

This function initializes the circular buffer, setting the front and rear indices to 0 and the count to 0. It also initializes the mutex and condition variables.

- free_file_info Function

```
void free_file_info(file_info_t *file_info) { //func for free memory allocated for file info
    free(file_info->src_path);
    free(file_info->dest_path);
}
```

free_file_info function is designed to release memory that was dynamically allocated for the file paths within a file_info_t structure. This is necessary to avoid memory leaks, which occur when dynamically allocated memory is not properly deallocated.

- Enqueue Function

```
void enqueue(file_info_t file_info) { //function for add file info to buffer
    pthread_mutex_lock(&buffer.mutex);

    while (buffer.count == buffer_size) // wait if buffer is full
        pthread_cond_wait(&buffer.cond_full, &buffer.mutex);

    // add file information to the buffer
    buffer.buffer[buffer.rear] = file_info;
    buffer.rear = (buffer.rear + 1) % buffer_size;
    buffer.count++;

    // signal that the buffer is not empty
    pthread_cond_signal(&buffer.cond_empty);
    pthread_mutex_unlock(&buffer.mutex);
}
```

The enqueue function adds file information to the buffer. If the buffer is full, the function waits until a slot becomes available. After enqueueing, it signals that the buffer is not empty.

- Dequeue Function

```
file_info_t dequeue() { //func for remove and return file info from buffer
    file_info_t file_info;
    pthread_mutex_lock(&buffer.mutex);

    //wait if buffer is empty
    while (buffer.count == 0)
        pthread_cond_wait(&buffer.cond_empty, &buffer.mutex);

    //remove file information from the buffer
    file_info = buffer.buffer[buffer.front];
    buffer.front = (buffer.front + 1) % buffer_size;
    buffer.count--;

    //signal that the buffer is not full
    pthread_cond_signal(&buffer.cond_full);
    pthread_mutex_unlock(&buffer.mutex);

    return file_info;
}
```

The dequeue function removes and returns file information from the buffer. If the buffer is empty, the function waits until an item is available. After dequeuing, it signals that the buffer is not full.

- Manager Thread Function

```

void *manager(void *arg) { //manager thread function to read directory contents and enqueue files
    DIR *src_dir_stream;
    struct dirent *src_dir_entry;
    struct stat src_stat;
    file_info_t file_info = {0};
    char *src_path, *dest_path;
    size_t src_path_len, dest_path_len;

    src_dir_stream = opendir(src_dir); //open the source directory
    if (src_dir_stream == NULL) {
        perror("Failed to open source directory");
        error_handler("Failed to open source directory");
    }

    while ((src_dir_entry = readdir(src_dir_stream)) != NULL) { //read entries in the source directory
        if (strcmp(src_dir_entry->d_name, ".") == 0 || strcmp(src_dir_entry->d_name, "..") == 0)
            continue;

        //calculate lengths for source and destination paths
        src_path_len = strlen(src_dir) + strlen(src_dir_entry->d_name) + 2;
        dest_path_len = strlen(dest_dir) + strlen(src_dir_entry->d_name) + 2;

        //allocate memory for source and destination paths
        src_path = malloc(src_path_len);
        dest_path = malloc(dest_path_len);

        if (src_path == NULL || dest_path == NULL) { //check memory allocation
            error_handler("Memory allocation failed");
        }

        //create full paths for source and destination
        snprintf(src_path, src_path_len, "%s/%s", src_dir, src_dir_entry->d_name);
        snprintf(dest_path, dest_path_len, "%s/%s", dest_dir, src_dir_entry->d_name);

        if (stat(src_path, &src_stat) == -1) { //get status of the source file
            perror("Failed to get source file status");
            free(src_path);
            free(dest_path);
            continue;
        }

        if (S_ISDIR(src_stat.st_mode)) { //check if the entry is a directory
            if (mkdir(dest_path, src_stat.st_mode) == -1 && errno != EEXIST) { //handle directories recursively
                perror("Failed to create destination directory");
                free(src_path);
                free(dest_path);
                continue;
            }
        }

        //temporarily change directories and recurse
        char *prev_src_dir = src_dir;
        char *prev_dest_dir = dest_dir;
        src_dir = src_path;
        dest_dir = dest_path;
        manager(NULL); //recurse for the subdirectory
        src_dir = prev_src_dir;
        dest_dir = prev_dest_dir;

        free(src_path);
        free(dest_path);
        num_directories_copied++; //increment the number of directories copied
    } else {
        file_info.src_fd = open(src_path, O_RDONLY); //open source file
        if (file_info.src_fd == -1) {
            perror("Failed to open source file");
            free(src_path);
            free(dest_path);
            continue;
        }

        file_info.dest_fd = open(dest_path, O_WRONLY | O_CREAT | O_TRUNC, src_stat.st_mode); //open destination file
        if (file_info.dest_fd == -1) {
            perror("Failed to open destination file");
            close(file_info.src_fd);
            free(src_path);
            free(dest_path);
            continue;
        }

        file_info.src_path = src_path;
        file_info.dest_path = dest_path;

        enqueue(file_info); //enqueue the file information
        num_files_copied++; //increment the number of files copied
    }

    closedir(src_dir_stream); //close the source directory
    done_flag = 1; //set flag for processing is complete
    pthread_cond_broadcast(&buffer.cond_empty); //wake up all worker threads
}

return NULL;
}

```

The manager function opens the source directory and iterates through its contents. For each file, it creates the corresponding destination path and enqueues the file information. If a directory is encountered, it handles it recursively.

- Worker Thread Function

```
void *worker(void *arg) { //worker thread function for copy files from source to destination
    file_info_t file_info;
    char buffer_temp[buffer_size];
    ssize_t bytes_read, bytes_written;
    size_t bytes_copied;

    pthread_barrier_wait(&barrier); //wait at the barrier

    while (!done_flag || buffer.count > 0) { //process files until flag is set and buffer is empty
        file_info = dequeue();
        bytes_copied = 0;
        while ((bytes_read = read(file_info.src_fd, buffer_temp, buffer_size)) > 0) { //copy data from source file to destination file
            bytes_written = write(file_info.dest_fd, buffer_temp, bytes_read);
            if (bytes_written != bytes_read)
                error_handler("Failed to write to destination file");
            bytes_copied += bytes_written;
        }

        if (bytes_read == -1)
            error_handler("Failed to read from source file");

        //update total bytes copied
        pthread_mutex_lock(&stats_mutex);
        total_bytes_copied += bytes_copied;
        pthread_mutex_unlock(&stats_mutex);

        //close file descriptors
        close(file_info.src_fd);
        close(file_info.dest_fd);

        printf("Copied %s to %s\n", file_info.src_path, file_info.dest_path);
        free_file_info(&file_info); //free allocated memory for file paths
    }

    return NULL;
}
```

The worker function waits at the barrier to synchronize with other threads. It then enters a loop where it dequeues file information and performs the file copy operation. The loop continues until all files are processed and the buffer is empty.

- Main Function

```

int main(int argc, char *argv[]) { //main func for set up and start manager and worker threads
    if (argc != 5) {
        fprintf(stderr, "Usage: %s <buffer_size> <num_workers> <source_dir> <dest_dir>\n", argv[0]);
        return 1;
    }

    buffer_size = atoi(argv[1]); //get buffer size
    num_workers = atoi(argv[2]); //get number of worker threads
    src_dir = argv[3]; //get source directory path
    dest_dir = argv[4]; //get destination directory path

    init_buffer(); // init the buffer

    pthread_barrier_init(&barrier, NULL, num_workers + 1); //initialize the barrier

    struct timeval start_time, end_time;
    gettimeofday(&start_time, NULL); //start time measurement

    pthread_t manager_thread, worker_threads[num_workers]; //create manager and worker threads
    pthread_create(&manager_thread, NULL, manager, NULL);
    for (int i = 0; i < num_workers; i++)
        pthread_create(&worker_threads[i], NULL, worker, NULL);

    pthread_barrier_wait(&barrier); //wait at the barrier in the main thread

    pthread_join(manager_thread, NULL); //wait for manager and worker threads to complete
    for (int i = 0; i < num_workers; i++)
        pthread_join(worker_threads[i], NULL);

    pthread_barrier_destroy(&barrier); //destroy the barrier
    free(buffer.buffer); //free dynamically allocated buffer memory

    gettimeofday(&end_time, NULL); //end time measurement

    //calculate execution time in milliseconds
    long execution_time_ms = (end_time.tv_sec - start_time.tv_sec) * 1000 +
    (end_time.tv_usec - start_time.tv_usec) / 1000;

    printf("//////////////////////STATISTIC//////////////////////\n");
    printf("Execution time: %ld ms\n", execution_time_ms);
    printf("Number of files copied: %d\n", num_files_copied);
    printf("Number of directories copied: %d\n", num_directories_copied);
    printf("Total bytes copied: %zu\n", total_bytes_copied);
    printf("Buffer size: %d\n", buffer_size);
    printf("Number of worker threads: %d\n", num_workers);

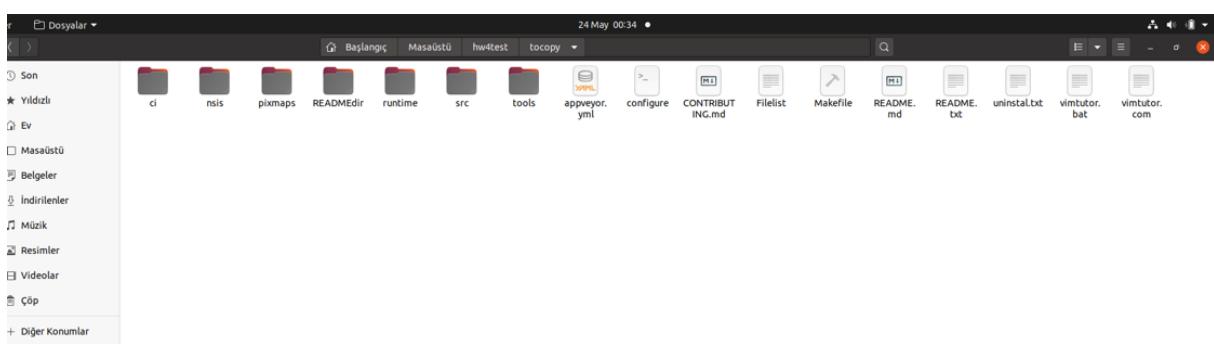
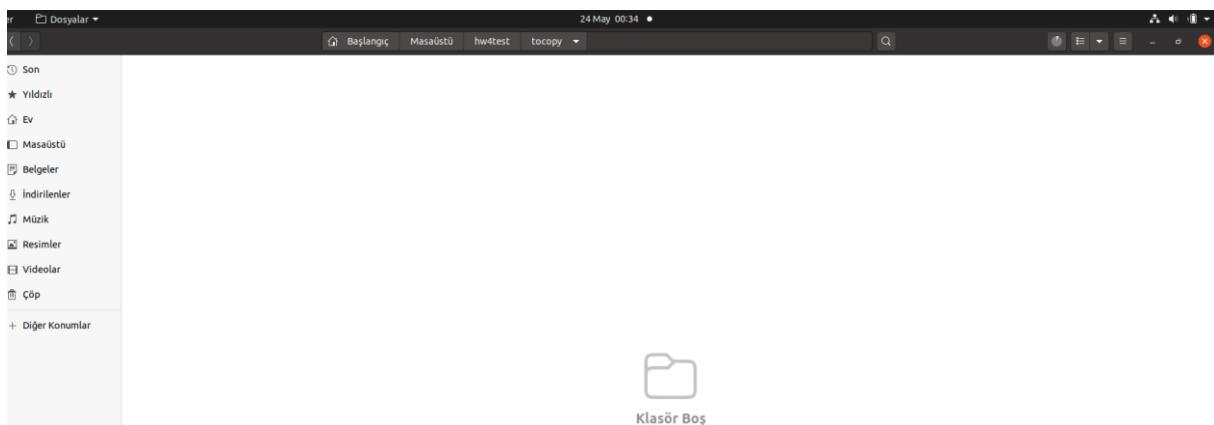
    return 0;
}

```

The main function initializes the buffer, barrier, and creates the manager and worker threads. It then waits for all threads to complete their tasks before exiting. At the end it prints the STATICS .

OUTPUT

**1. valgrind ./MWCp 10 10 ..//testdir/src/libvterm ..//tocopy
(THERE IS NO MEMORY LEAK)**



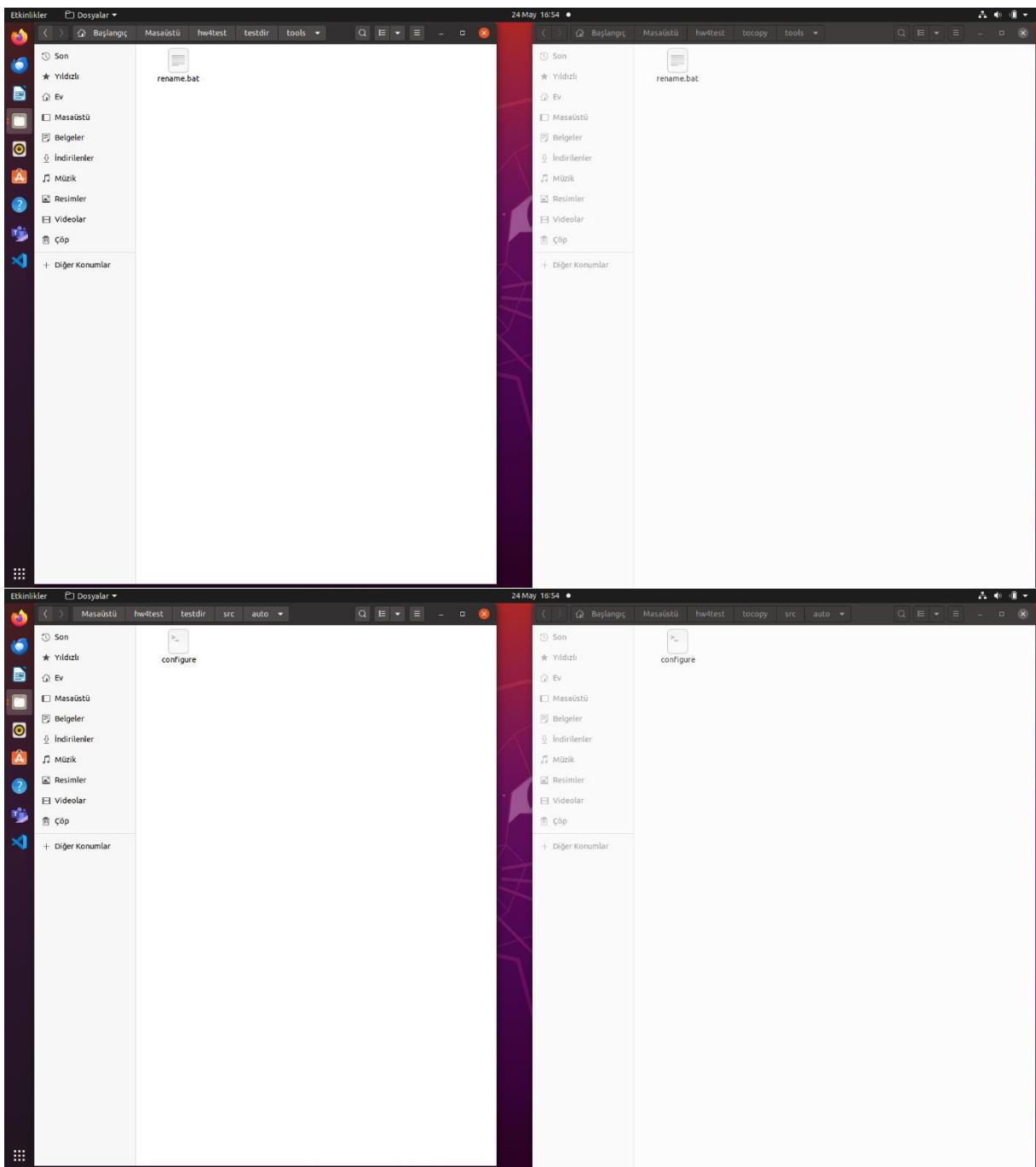
2. /MWCp 10 4 ..//testdir/src/ libvterm/src ..//toCopy

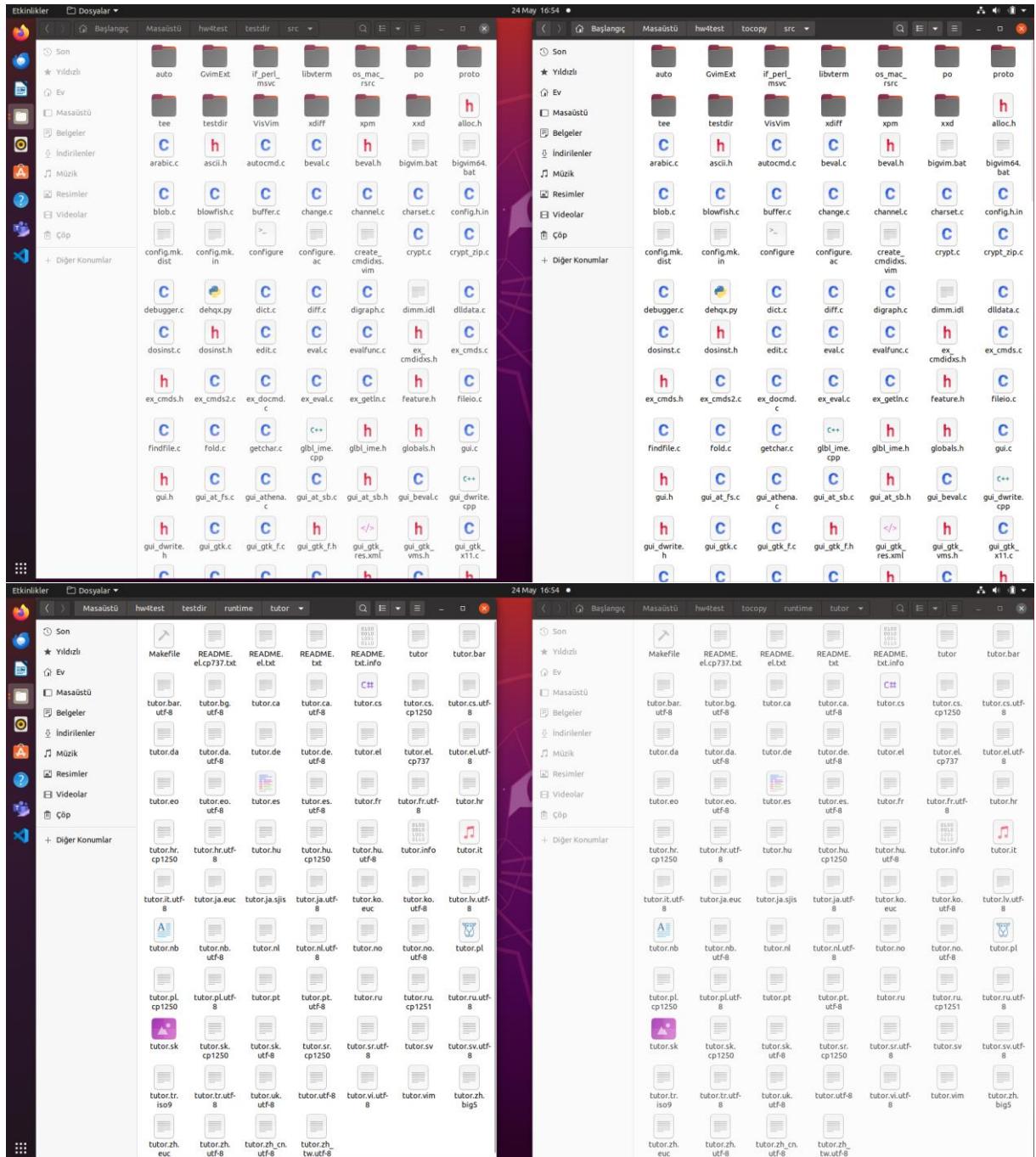
3. ./MWCp 10 10 ..//testdir/src/ libvterm/src ..//toCopy

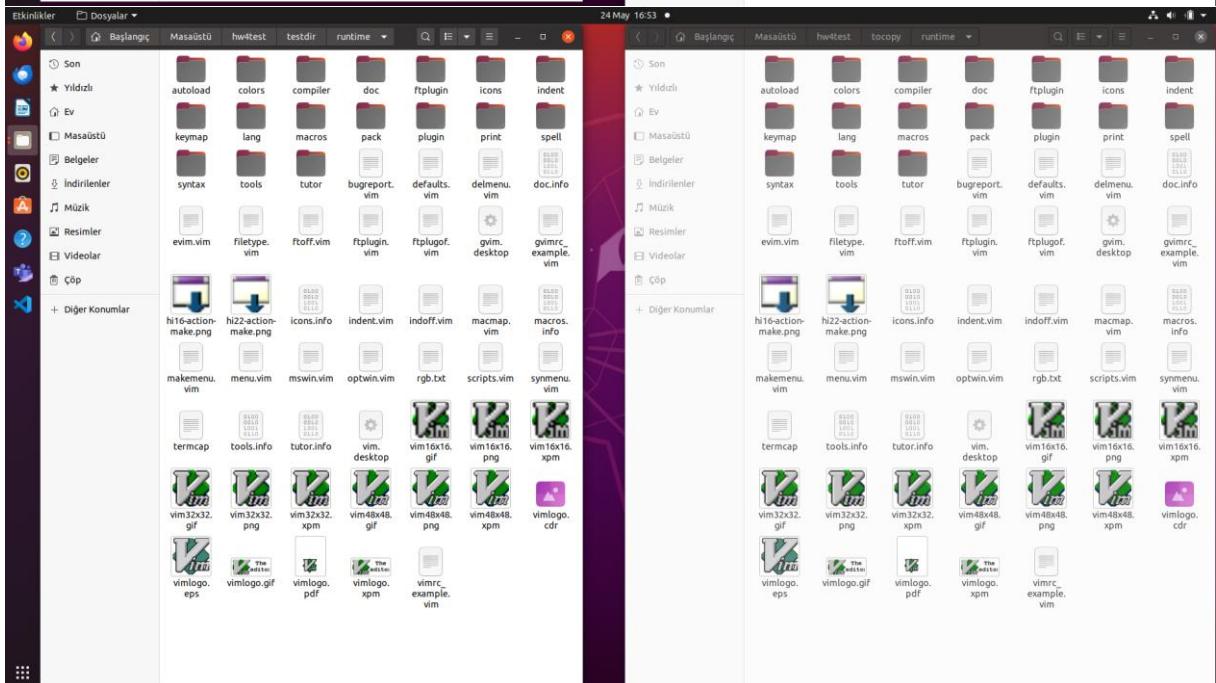
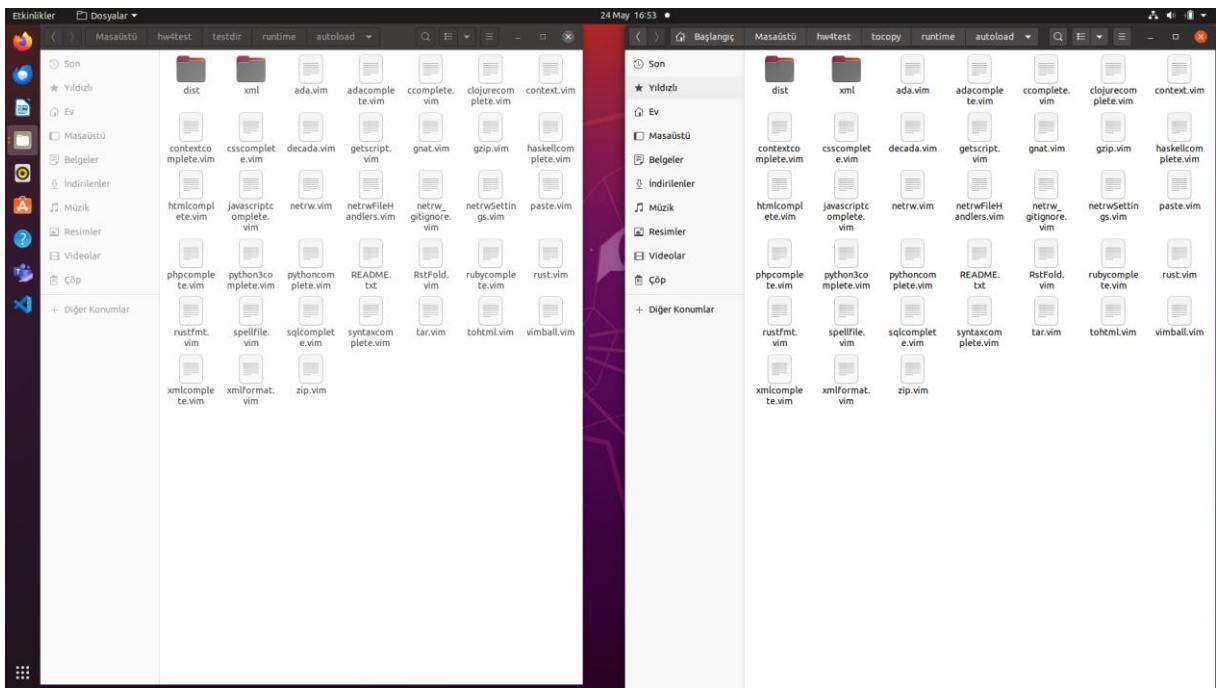
4. ./MWCp 100 4 ./testdir/src/ libvterm/src ..toCopy

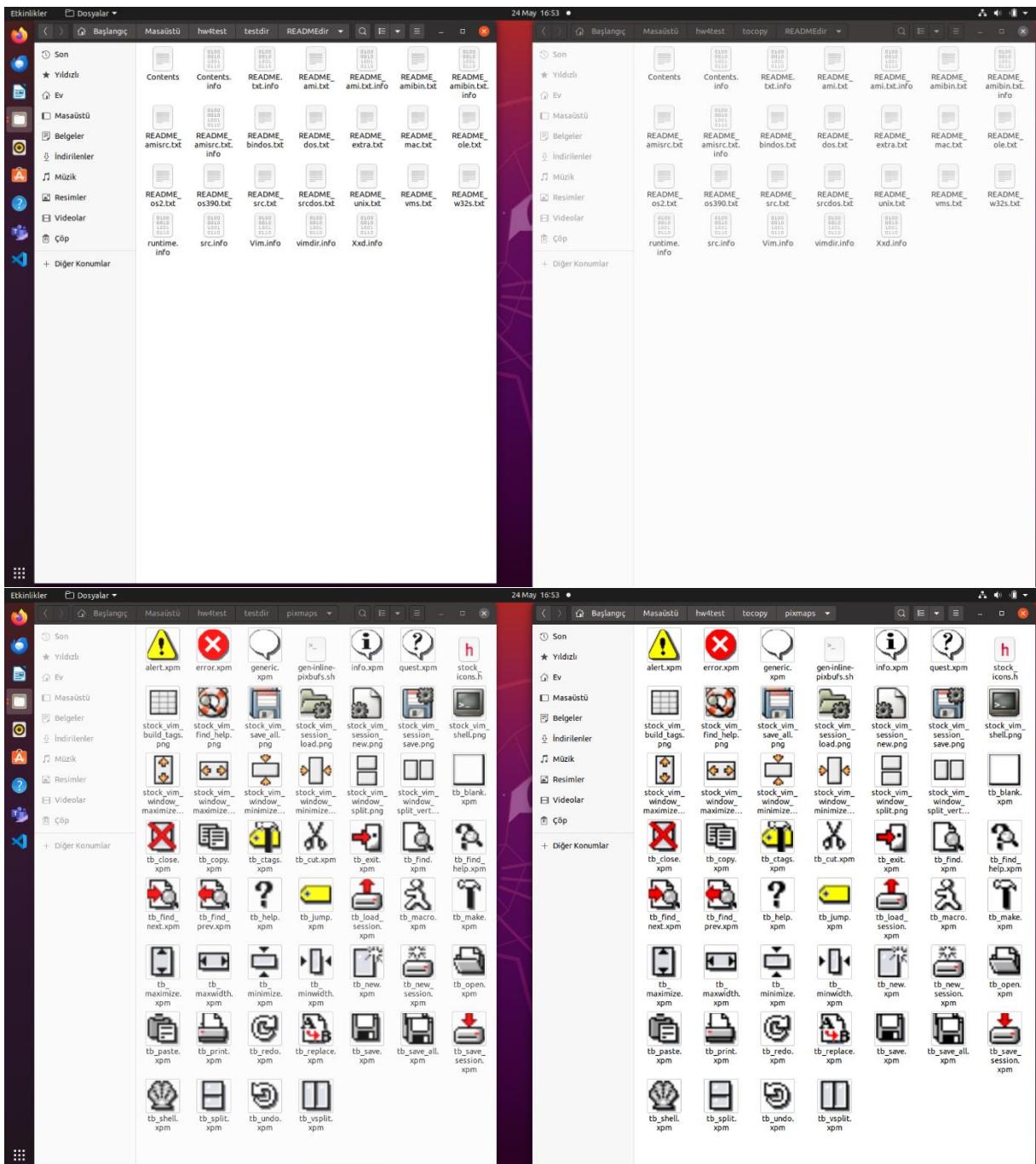
```
alper@alper-VirtualBox:~/Masaüstü/hwtest/put_your_codes_here$ ./MWCp 100 4 "/home/alper/Masaüstü/hwtest/testdir" "/home/alper/Masaüstü/hw4test/toCopy"
Copied /home/alper/Masaüstü/hw4test/testdir/nsis/lang/japanese.nsi to /home/alper/Masaüstü/hw4test/toCopy/nsis/lang/japanese.nsi
Copied /home/alper/Masaüstü/hw4test/testdir/nsis/lang/english.nsi to /home/alper/Masaüstü/hw4test/toCopy/nsis/lang/english.nsi
Copied /home/alper/Masaüstü/hw4test/testdir/nsis/lang/simplechinese.nsi to /home/alper/Masaüstü/hw4test/toCopy/nsis/lang/simplechinese.nsi
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Copied /home/alper/Masaüstü/hw4test/testdir/nsis/lang/vi_national.nsi to /home/alper/Masaüstü/hw4test/toCopy/nsis/lang/vi_national.nsi
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Copied /home/alper/Masaüstü/hw4test/testdir/Content.info to /home/alper/Masaüstü/hw4test/toCopy/READMEdir/Content.info
Copied /home/alper/Masaüstü/hw4test/testdir/README_os2.txt to /home/alper/Masaüstü/hw4test/toCopy/READMEdir/README_os2.txt
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Copied /home/alper/Masaüstü/hw4test/testdir/README_anisrc.txt to /home/alper/Masaüstü/hw4test/toCopy/READMEdir/README_anisrc.txt
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Copied /home/alper/Masaüstü/hw4test/testdir/READMEdir/runtime.info to /home/alper/Masaüstü/hw4test/toCopy/READMEdir/runtime.info
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Copied /home/alper/Masaüstü/hw4test/testdir/README_amil.txt.info to /home/alper/Masaüstü/hw4test/toCopy/READMEdir/README_amil.txt.info
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Copied /home/alper/Masaüstü/hw4test/testdir/README_w32s.txt to /home/alper/Masaüstü/hw4test/toCopy/READMEdir/README_w32s.txt
Copied /home/alper/Masaüstü/hw4test/testdir/README_mac.txt to /home/alper/Masaüstü/hw4test/toCopy/READMEdir/README_mac.txt
Copied /home/alper/Masaüstü/hw4test/testdir/README_ole.txt to /home/alper/Masaüstü/hw4test/toCopy/READMEdir/README_ole.txt
Copied /home/alper/Masaüstü/hw4test/testdir/uninstall.txt to /home/alper/Masaüstü/hw4test/toCopy/uninstall.txt
Copied /home/alper/Masaüstü/hw4test/testdir/vimtutor.bat to /home/alper/Masaüstü/hw4test/toCopy/vimtutor.bat
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Copied /home/alper/Masaüstü/hw4test/testdir/src/edit.c to /home/alper/Masaüstü/hw4test/toCopy/src/edit.c
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Copied /home/alper/Masaüstü/hw4test/testdir/src/option.c to /home/alper/Masaüstü/hw4test/toCopy/src/option.c
Copied /home/alper/Masaüstü/hw4test/testdir/src/menfile_test.c to /home/alper/Masaüstü/hw4test/toCopy/src/menfile_test.c
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Copied /home/alper/Masaüstü/hw4test/testdir/src/ViSVn/StdAfx.cpp to /home/alper/Masaüstü/hw4test/toCopy/src/ViSVn/StdAfx.cpp
alper@alper-VirtualBox:~/Masaüstü/hw4test/put_your_codes_here$ ./MWCp 100 4 "/home/alper/Masaüstü/hw4test/testdir/pixmaps" "/home/alper/Masaüstü/hw4test/toCopy/pixmaps"
Copied /home/alper/Masaüstü/hw4test/testdir/pixmaps/stock_icons.h to /home/alper/Masaüstü/hw4test/toCopy/pixmaps/stock_icons.h
Copied /home/alper/Masaüstü/hw4test/testdir/pixmaps/question.xpm to /home/alper/Masaüstü/hw4test/toCopy/pixmaps/question.xpm
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Copied /home/alper/Masaüstü/hw4test/testdir/pixmaps/gen-inline-pixbufs.x to /home/alper/Masaüstü/hw4test/toCopy/pixmaps/gen-inline-pixbufs.x
Copied /home/alper/Masaüstü/hw4test/testdir/pixmaps/tb_cut.xpm to /home/alper/Masaüstü/hw4test/toCopy/pixmaps/tb_cut.xpm
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Copied /home/alper/Masaüstü/hw4test/testdir/pixmaps/github/ISSUE_TEMPLATE/bug_report.md to /home/alper/Masaüstü/hw4test/toCopy/github/ISSUE_TEMPLATE/bug_report.md
Copied /home/alper/Masaüstü/hw4test/testdir/pixmaps/tb_exit.xpm to /home/alper/Masaüstü/hw4test/toCopy/pixmaps/tb_exit.xpm
Copied /home/alper/Masaüstü/hw4test/testdir/travis.yml to /home/alper/Masaüstü/hw4test/toCopy/travis.yml
Copied /home/alper/Masaüstü/hw4test/testdir/libvterm/src/lsl1551098739430.pdf to /home/alper/Masaüstü/hw4test/toCopy/src/lsl1551098739430.pdf
////////////////////////////////////////////////////////////////STATISTIC////////////////////////////////////////////////////////////////
Execution time: 630 ms
Number of files copied: 3116
Number of directories copied: 151
Total bytes copied: 73520554
Buffer size: 100
Number of worker threads: 4
alper@alper-VirtualBox:~/Masaüstü/hw4test/put_your_codes_here$
```

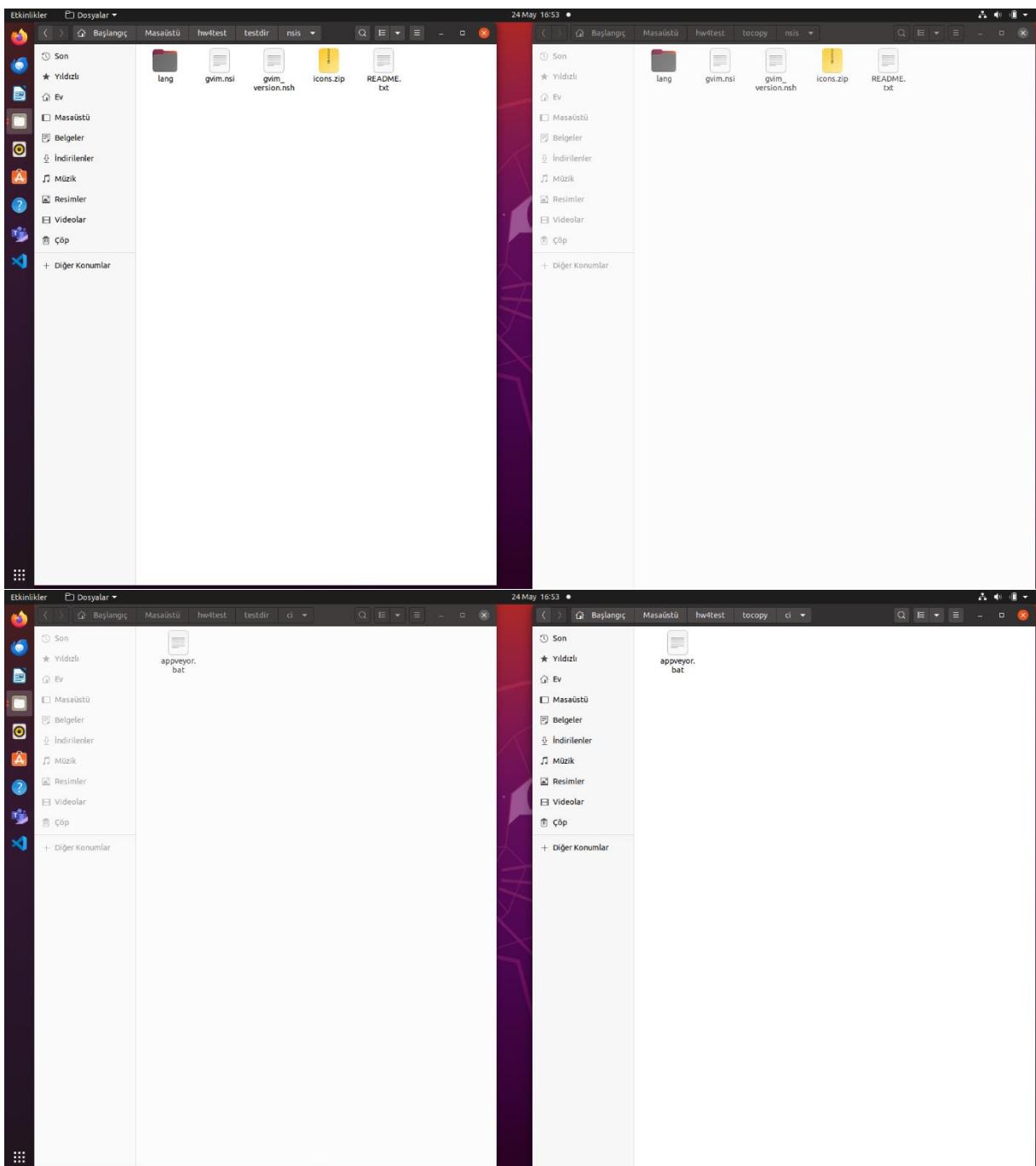
FILE

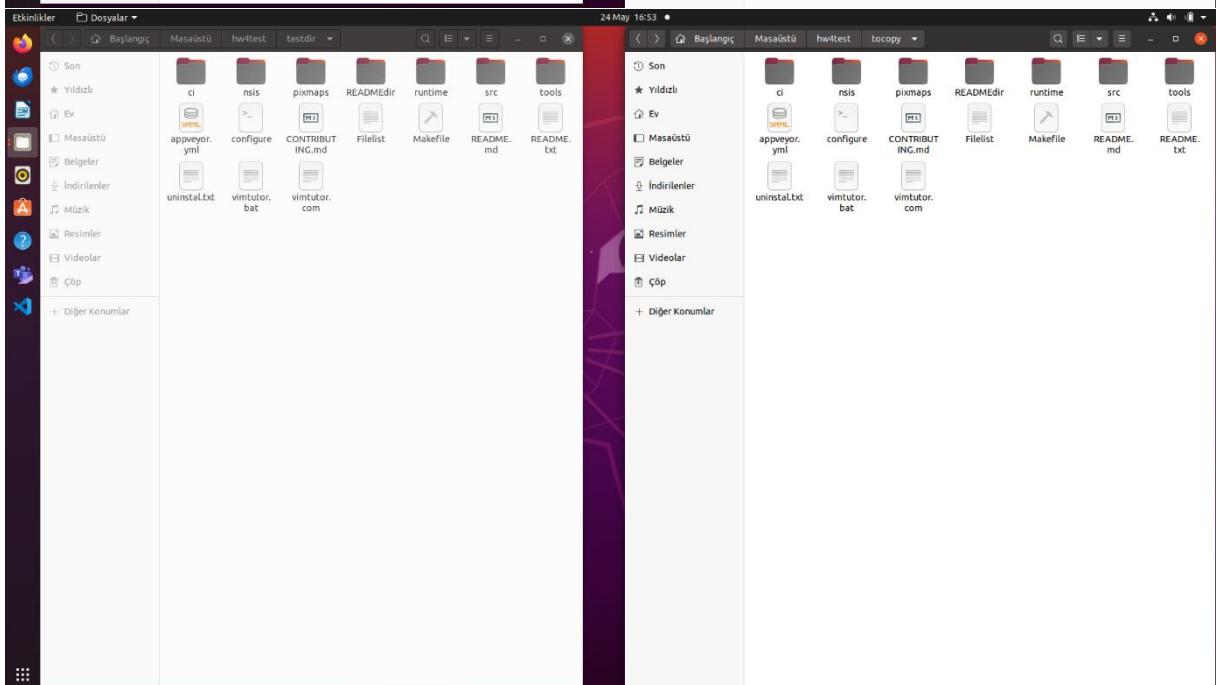
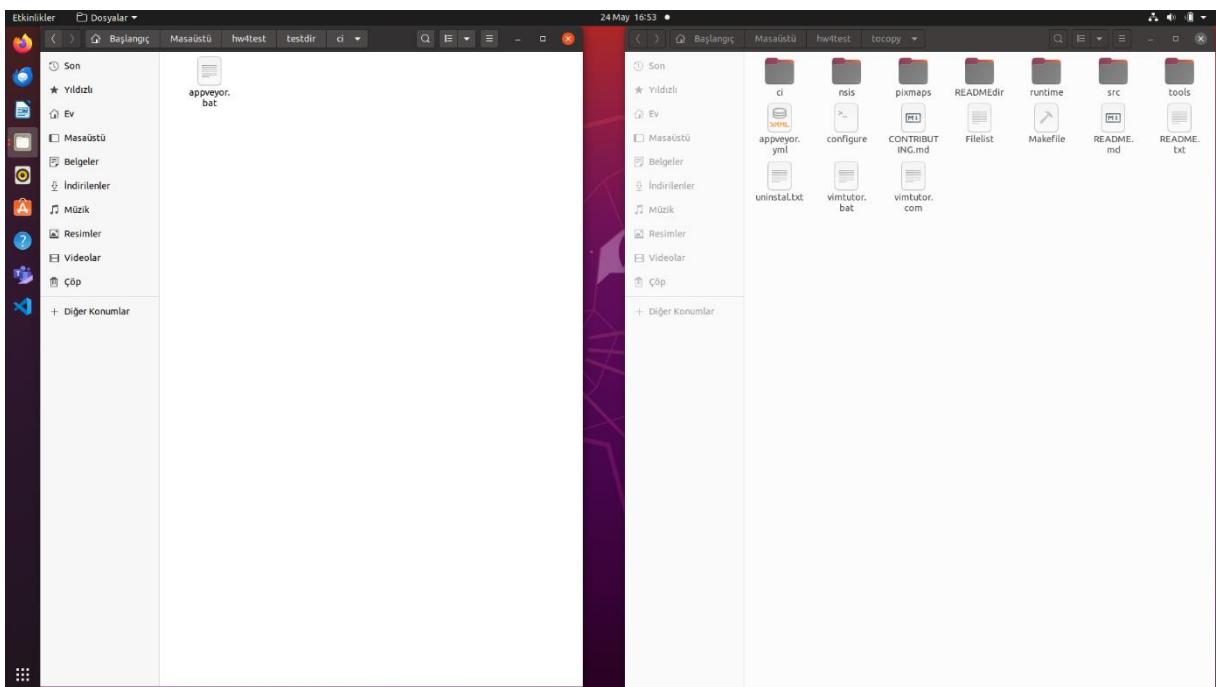












MAKEFILE

The screenshot shows a Linux desktop environment with a terminal window and a code editor.

Terminal Window:

```
alper@alper-VirtualBox:~/Masaüstü/hw4test/put_your_codes_here$ make
```

Code Editor:

The code editor displays a file named `makefile` with the following content:

```
all : clean compile
compile :
    @gcc -g -o MMcp 1901042669_main.c -lpthread
clean :
    @rm -f *.o
    @rm -f MMcp
11
```

The screenshot shows a Linux desktop environment with a terminal window and a code editor.

Terminal Window:

```
alper@alper-VirtualBox:~/Masaüstü/hwtest/put_your_codes_here$ make  
alper@alper-VirtualBox:~/Masaüstü/hwtest/put_your_codes_here$
```

Code Editor:

The code editor displays a file named "makefile" with the following content:

```
1 all : clean compile  
2  
3 compile :  
4     @gcc -g -o MWcp 1901042669_main.c -lpthread  
5  
6  
7 clean :  
8     @rm -f *.o  
9     @rm -f MWcp  
10  
11
```

```
alper@alper-VirtualBox:~/Masasutu/hw4test/put_your_codes_here$ makefile
alper@alper-VirtualBox:~/Masasutu/hw4test/put_your_codes_here$ ./MKcp 100 10 "/home/alper/Masasutu/hw4test/testdir" "/home/alper/Masasutu/hw4test/tocopy"
Copied /home/alper/Masasutu/hw4test/testdir/nsis/lang/japanese.nsi to /home/alper/Masasutu/hw4test/testcopy/nsis/lang/japanese.nsi
Copied /home/alper/Masasutu/hw4test/testdir/nsis/gvln.nsi to /home/alper/Masasutu/hw4test/tocopy/nsis/gvln.nsi
Copied /home/alper/Masasutu/hw4test/testdir/nsis/README.txt to /home/alper/Masasutu/hw4test/tocopy/nsis/README.txt
Copied /home/alper/Masasutu/hw4test/testdir/nsis/lang/english.nsi to /home/alper/Masasutu/hw4test/tocopy/nsis/lang/english.nsi
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/README_amsrc.txt.info to /home/alper/Masasutu/hw4test/tocopy/READMEDir/README_amsrc.txt.info
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Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/README_srcdos.txt to /home/alper/Masasutu/hw4test/tocopy/READMEDir/README_srcdos.txt
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/README_src.txt to /home/alper/Masasutu/hw4test/tocopy/READMEDir/README_src.txt
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/Contents to /home/alper/Masasutu/hw4test/tocopy/READMEDir/Contents
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/README_0s2.txt to /home/alper/Masasutu/hw4test/tocopy/READMEDir/README_0s2.txt
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/README_aml.txt to /home/alper/Masasutu/hw4test/tocopy/READMEDir/README_aml.txt
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/README_amsrc.txt to /home/alper/Masasutu/hw4test/tocopy/READMEDir/README_amsrc.txt
Copied /home/alper/Masasutu/hw4test/testdir/nsis/lang/dutch.nsi to /home/alper/Masasutu/hw4test/tocopy/nsis/lang/dutch.nsi
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/runtime.info to /home/alper/Masasutu/hw4test/tocopy/READMEDir/runtime.info
Copied /home/alper/Masasutu/hw4test/testdir/nsis/lang/tradchinese.nsi to /home/alper/Masasutu/hw4test/tocopy/nsis/lang/tradchinese.nsi
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/README_amlt.info to /home/alper/Masasutu/hw4test/tocopy/README_amlt.info
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/README_vms.info to /home/alper/Masasutu/hw4test/tocopy/READMEDir/README_vms.info
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/README_vms.txt to /home/alper/Masasutu/hw4test/tocopy/READMEDir/README_vms.txt
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/README_dos.txt to /home/alper/Masasutu/hw4test/tocopy/READMEDir/README_dos.txt
Copied /home/alper/Masasutu/hw4test/testdir/nsis/gvln_version.nsh to /home/alper/Masasutu/hw4test/tocopy/nsis/gvln_version.nsh
Copied /home/alper/Masasutu/hw4test/testdir/READMEDir/Contents.info to /home/alper/Masasutu/hw4test/tocopy/READMEDir/Contents.info
```

makefile

```
all : clean compile
2
3 compile :
4     @gcc -g -o MKcp 1981042669_main.c -lpthread
5
6
7 clean :
8     @rm -f *.o
9     @rm -f MKcp
10
11
```

```
alper@alper-VirtualBox:~/Masaüstü/hwTest/put_your_codes_here
```

```
st/tocopy/pixmaps/tb_save_session.xpm
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_blank.xpm to /home/alper/Masaüstü/hwTest/to
pixmaps/tb_blank.xpm
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/stock_vim_window_minimize.png to /home/alper/Masa
ustu/hwTest/tocopy/pixmaps/stock_vim_window_minimize.png
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_load_session.xpm to /home/alper/Masaüstü/hwTe
st/tocopy/pixmaps/tb_load_session.xpm
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_replace.xpm to /home/alper/Masaüstü/hwTest/to
copy/pixmaps/tb_replace.xpm
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/gen-inlne-pixbufs.sh to /home/alper/Masaüstü/hw4
test/tocopy/pixmaps/gen-inlne-pixbufs.sh
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_cut.xpm to /home/alper/Masaüstü/hwTest/toco
/pixmaps/tb_cut.xpm
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/stock_vim_session_save.png to /home/alper/Masa
ustu/hwTest/tocopy/pixmaps/stock_vim_session_save.png
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/stock_vim_session_new.png to /home/alper/Masa
ustu/hwTest/tocopy/pixmaps/stock_vim_session_new.png
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/stock_vim_window_maximize.png to /home/alper/Masa
ustu/hwTest/tocopy/pixmaps/stock_vim_window_maximize.png
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_help.xpm to /home/alper/Masaüstü/hw4test/toco
/pixmaps/tb_help.xpm
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_close.xpm to /home/alper/Masaüstü/hwTest/toco
/pixmaps/tb_close.xpm
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_exit.xpm to /home/alper/Masaüstü/hwTest/toco
/pixmaps/tb_exit.xpm
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_feature_request.md to /home/alper/Masa
ustu/hwTest/tocopy/github/ISSUE_TEMPLATE/feature_request.md
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_bug_report.md to /home/alper/Masa
ustu/hwTest/tocopy/github/ISSUE_TEMPLATE/bug_report.md
Copied /home/alper/Masaüstü/hwTest/testdir/travis.yml to /home/alper/Masaüstü/hwTest/tocopy/trav
is.yml
Copied /home/alper/Masaüstü/hwTest/testdir/README.txt to /home/alper/Masaüstü/hwTest/tocopy/README.
txt
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_minimize.xpm to /home/alper/Masaüstü/hwTest/t
ocopy/pixmaps/tb_minimize.xpm
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/tb_find.xpm to /home/alper/Masaüstü/hw4test/toco
/pixmaps/tb_find.xpm
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/stock_vim_build_tags.png to /home/alper/Masa
ustu/hwTest/tocopy/pixmaps/stock_vim_build_tags.png
Copied /home/alper/Masaüstü/hwTest/testdir/pixmaps/stock_icONS.h to /home/alper/Masaüstü/hwTest/toc
opy/pixmaps/stock_icONS.h
Copied /home/alper/Masaüstü/hwTest/testdir/runtime/autoload/phpcomplete.vim to /home/alper/Masa
ustu/hwTest/testdir/runtime/autoload/phpcomplete.vim
Copied /home/alper/Masaüstü/hwTest/testdir/runtime/autoload/netrw.vim to /home/alper/Masaüstü/hwTe
st/tocopy/runtime/autoload/netrw.vim
Copied /home/alper/Masaüstü/hwTest/testdir/src/lbvttern/src/lsl1551898739430.pdf to /home/alper/Masa
ustu/hwTest/tocopy/src/lbvttern/src/lsl1551898739430.pdf
////////////////////////////////////////////////////////////////STATISTICS////////////////////////////////////////////////////////////////
Execution time: 0.000000
Number of files copied: 3116
Number of directories copied: 151
Total bytes copied: 73526554
Buffer size: 100
Number of worker threads: 10
```