



GTU Department of Computer Engineering
CSE 344 - Spring 2023
Homework 5 Report

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1 Critical Sections

1.1 stdout and stderr

To provide mutual exclusion for the standard output and standard error, `print_threadsafe` function is written. It takes the file descriptor and the mutex and the print format. An example usage for stdout could be `print_threadsafe(STDOUT_FILENO, &mutex_stdout, "Hello Netherlands\n");`

```
int print_threadsafe(int fd, pthread_mutex_t *fd_mutex, const char *format, ...)
{
    va_list args;
    int numbytes;

    if (pthread_mutex_lock(fd_mutex) != 0) {
        fprintf(stderr, "Failed to lock the mutex\n");
        return -1;
    }

    va_start(args, format);
    numbytes = vdprintf(fd, format, args);
    va_end(args);

    if (pthread_mutex_unlock(fd_mutex) != 0) {
        fprintf(stderr, "Failed to unlock the mutex\n");
        return -1;
    }

    return numbytes;
}
```

1.2 Shared buffer

Producer thread opens the source and destination files and push these open file descriptors with their file names to the shared job buffer. Consumer threads pop from the job buffer and apply read/write processes to successfully copy source file to destination file. Access to this shared buffer is a critical region between producer and consumers. To prevent race condition and provide mutual exclusion, critical region is protected with a mutex, and the empty/full buffer conditions are handled with two condition variables `cond_empty` and `cond_full`.

```

if (pthread_mutex_lock(&mutex_jobs_buff) != 0) {
    print_threadsafe(STDERR_FILENO, &mutex_stderr, "Failed to lock the mutex\n");
    exit(EXIT_FAILURE);
}

/* Add the copy structure to the producer-consumer buffer */
while (buff_push(&jobs_buff, job) == -1) {
    if (pthread_cond_wait(&cond_empty, &mutex_jobs_buff) != 0) {
        print_threadsafe(STDERR_FILENO, &mutex_stderr, "Failed to make conditional wait\n");
        exit(EXIT_FAILURE);
    }
}

if (pthread_cond_signal(&cond_full) != 0) {
    print_threadsafe(STDERR_FILENO, &mutex_stderr, "Failed to make conditional signal\n");
    exit(EXIT_FAILURE);
}

if (pthread_mutex_unlock(&mutex_jobs_buff) != 0) {
    print_threadsafe(STDERR_FILENO, &mutex_stderr, "Failed to unlock the mutex\n");
    exit(EXIT_FAILURE);
}

```

producer pushes new copy job

2 Special File Types

Producer thread checks type of the file and acts according to its type. For the regular files they are passed to the consumers via the shared job buffer. For the FIFO files, producer creates the files at the destination and continues with the next file/directory. For a symbolic link file, its link is first read and then created a new symbolic link file at the destination with that link.

```

/**
 * The seven standard Unix file types are regular, directory, symbolic link,
 * FIFO special, block special, character special, and socket as defined by POSIX
 */
You, 47 minutes ago | 1 author (You)
struct cp_stats {
    int num_cons;
    int buff_size;
    int num_dir;
    int num_regfile;
    int num_slink;
    int num_fifo;
    int num_unsupported;
    long totalbytes;
    double elapsed_time;
};

```

3 Open File Descriptor Limit

At the beginning of the main program a counting semaphore is created with the initial value as the maximum number of open file descriptor. This value is gathered by the `getrlimit()` from `sys/resource.h` library. The producer thread downs this semaphore before opening a file and the consumers up the semaphore after close calls on source and destination file descriptors. With this way the number of maximum open file never exceeds, and no error will occur. Another possible solution could be resetting the buffer size according to current # of max open file. By doing that we never reach the max

limit. However, this seems to me not user friendly, for that reason I prefer using counting semaphore for handling exceeding fd limit.

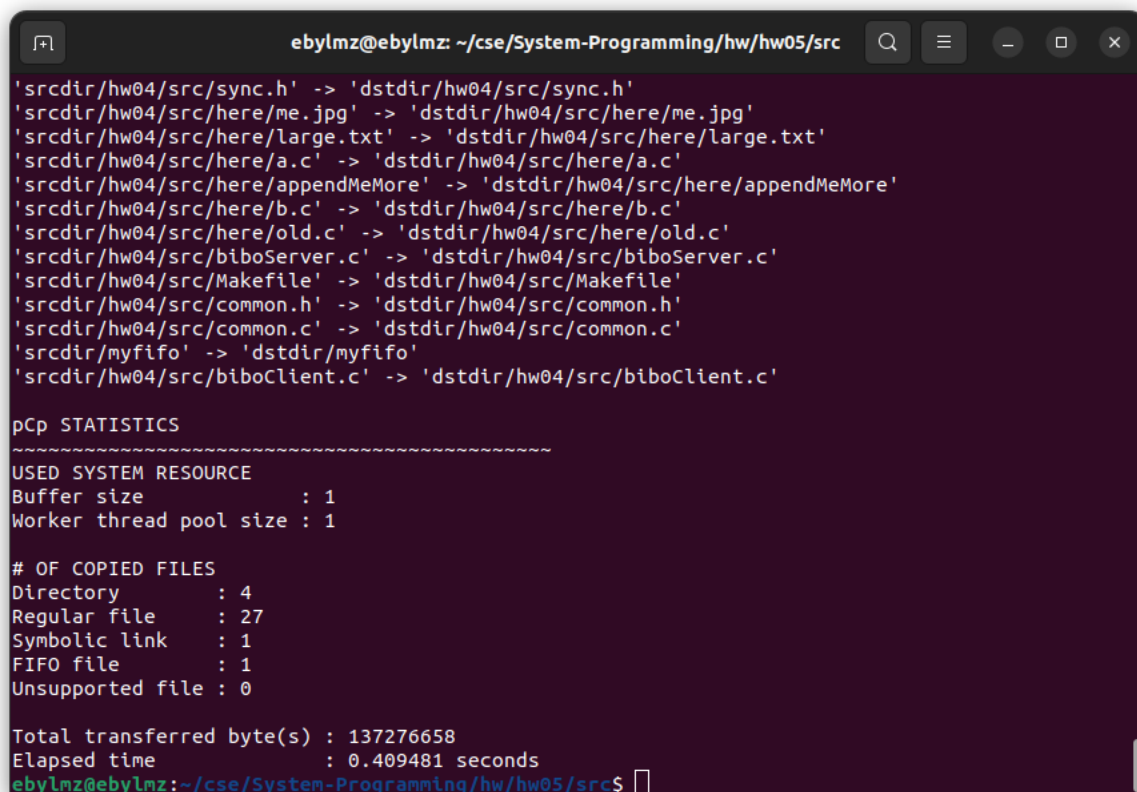
4 Signal Handling

A signal handler written for the signals SIGTERM and SIGINT. The handler sets a global flag variable which are checked on both producer and consumer threads. When the producer thread realizes this flag is up, then it stops reading directory and make conditional broadcast for consumer thread for graceful termination. When the consumer thread realizes it, stop checking the jobs buffer and closes all the resources and exits gracefully.

5 Experimenting Buffer and Number of Consumer parameters

In general, using a big/moderate buffer and keeping the size of thread pool moderate gives best performance. Even if the size of thread pool is big, if the buffer size is small then having big thread pool is just a waste of system resources. On the other hand, if the buffer is large and the thread pool is small then the buffer will quickly fill, and the producer blocked until a consumer pop from the buffer and wakes up the producer. Since the blocking chance of producer increase with the small buffer sizes, we cannot reach the optimum performance with these parameters.

5.1 Small Buffer, Small Consumer Thread Pool



```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src
'srcdir/hw04/src/sync.h' -> 'dstdir/hw04/src/sync.h'
'srcdir/hw04/src/here/me.jpg' -> 'dstdir/hw04/src/here/me.jpg'
'srcdir/hw04/src/here/large.txt' -> 'dstdir/hw04/src/here/large.txt'
'srcdir/hw04/src/here/a.c' -> 'dstdir/hw04/src/here/a.c'
'srcdir/hw04/src/here/appendMeMore' -> 'dstdir/hw04/src/here/appendMeMore'
'srcdir/hw04/src/here/b.c' -> 'dstdir/hw04/src/here/b.c'
'srcdir/hw04/src/here/old.c' -> 'dstdir/hw04/src/here/old.c'
'srcdir/hw04/src/biboServer.c' -> 'dstdir/hw04/src/biboServer.c'
'srcdir/hw04/src/Makefile' -> 'dstdir/hw04/src/Makefile'
'srcdir/hw04/src/common.h' -> 'dstdir/hw04/src/common.h'
'srcdir/hw04/src/common.c' -> 'dstdir/hw04/src/common.c'
'srcdir/myfifo' -> 'dstdir/myfifo'
'srcdir/hw04/src/biboClient.c' -> 'dstdir/hw04/src/biboClient.c'

pCp STATISTICS
~~~~~
USED SYSTEM RESOURCE
Buffer size          : 1
Worker thread pool size : 1

# OF COPIED FILES
Directory           : 4
Regular file        : 27
Symbolic link       : 1
FIFO file           : 1
Unsupported file    : 0

Total transferred byte(s) : 137276658
Elapsed time             : 0.409481 seconds
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```

5.2 Small Buffer, Large Consumer Thread Pool

```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src
'srcdir/hw04/src/common.h' -> 'dstdir/hw04/src/common.h'
'srcdir/hw04/src/common.c' -> 'dstdir/hw04/src/common.c'
'srcdir/hw04/src/biboClient.c' -> 'dstdir/hw04/src/biboClient.c'
'srcdir/hw04/report.pdf' -> 'dstdir/hw04/report.pdf'
'srcdir/large/a6.txt' -> 'dstdir/large/a6.txt'
'srcdir/large/a7.txt' -> 'dstdir/large/a7.txt'
'srcdir/large/a3.txt' -> 'dstdir/large/a3.txt'
'srcdir/large/a5.txt' -> 'dstdir/large/a5.txt'
'srcdir/hw04/src/here/large.txt' -> 'dstdir/hw04/src/here/large.txt'
'srcdir/large/a8.txt' -> 'dstdir/large/a8.txt'
'srcdir/large/a4.txt' -> 'dstdir/large/a4.txt'
'srcdir/large/a2.txt' -> 'dstdir/large/a2.txt'
'srcdir/large/a1.txt' -> 'dstdir/large/a1.txt'

pCp STATISTICS
~~~~~
USED SYSTEM RESOURCE
Buffer size          : 10
Worker thread pool size : 500

# OF COPIED FILES
Directory            : 4
Regular file         : 27
Symbolic link        : 1
FIFO file            : 1
Unsupported file     : 0

Total transferred byte(s) : 137276658
Elapsed time           : 0.315263 seconds
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```

5.3 Large Buffer, Large Thread Pool

```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src
'srcdir/large/a8.txt' -> 'dstdir/srcdir/large/large/a8.txt'
'srcdir/large/a3.txt' -> 'dstdir/srcdir/large/large/a3.txt'
'srcdir/large/a1.txt' -> 'dstdir/srcdir/large/large/a1.txt'
'srcdir/large/a4.txt' -> 'dstdir/srcdir/large/large/a4.txt'
'srcdir/large/a5.txt' -> 'dstdir/srcdir/large/large/a5.txt'
'srcdir/hw04/src/here/large.txt' -> 'dstdir/srcdir/hw04/hw04/src/src/here/here/large.txt'

pCp STATISTICS
~~~~~
USED SYSTEM RESOURCE
Buffer size          : 5000
Worker thread pool size : 1000

# OF COPIED FILES
Directory            : 4
Regular file         : 27
Symbolic link        : 1
FIFO file            : 1
Unsupported file     : 0

Total transferred byte(s) : 137276658
Elapsed time           : 0.217036 seconds
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```

5.4 Large Buffer, Moderate Thread Pool

```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src
'srcdir/hw04/src/common.c' -> 'dstdir/hw04/src/common.c'
'srcdir/hw04/src/biboClient.c' -> 'dstdir/hw04/src/biboClient.c'
'srcdir/hw04/src/sync.c' -> 'dstdir/hw04/src/sync.c'
'srcdir/hw04/src/here/me.jpg' -> 'dstdir/hw04/src/here/me.jpg'
'srcdir/large/a8.txt' -> 'dstdir/large/a8.txt'
'srcdir/large/a3.txt' -> 'dstdir/large/a3.txt'
'srcdir/large/a5.txt' -> 'dstdir/large/a5.txt'
'srcdir/hw04/src/here/large.txt' -> 'dstdir/hw04/src/here/large.txt'
'srcdir/large/a2.txt' -> 'dstdir/large/a2.txt'
'srcdir/large/a6.txt' -> 'dstdir/large/a6.txt'
'srcdir/large/a7.txt' -> 'dstdir/large/a7.txt'
'srcdir/large/a4.txt' -> 'dstdir/large/a4.txt'
'srcdir/large/a1.txt' -> 'dstdir/large/a1.txt'

pCp STATISTICS
~~~~~
USED SYSTEM RESOURCE
Buffer size      : 2000
Worker thread pool size : 50

# OF COPIED FILES
Directory       : 4
Regular file    : 27
Symbolic link   : 1
FIFO file       : 1
Unsupported file : 0

Total transferred byte(s) : 137276658
Elapsed time           : 0.141598 seconds
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```

6 Test Cases & Results

6.1 Content of Source Directory

Source directory contains 1 FIFO file, 1 symbolic link and several regular files in different format (text/binary) with different sizes.

```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$ ls -lR srcdir/
srcdir:
total 44
-rw-rw-r-- 2 ebylmz ebylmz 35677 May 29 09:58 hardlink
drwxrwxr-x 3 ebylmz ebylmz 4096 Jun 1 09:12 hw04
drwxrwxr-x 2 ebylmz ebylmz 4096 Jun 2 16:16 large
prw-rw-r-- 1 ebylmz ebylmz 0 May 28 21:24 myfifo
lrwxrwxrwx 1 ebylmz ebylmz 15 Jun 1 09:13 symlink -> hw04/src/sync.c

srcdir/hw04:
total 1900
-rw-rw-r-- 1 ebylmz ebylmz 148142 May 29 09:58 hw4.pdf
-rwxrwxr-x 1 ebylmz ebylmz 22536 May 29 09:58 pCp
-rw-rw-r-- 1 ebylmz ebylmz 1761946 May 29 09:58 report.pdf
drwxrwxr-x 3 ebylmz ebylmz 4096 May 29 09:58 src

srcdir/hw04/src:
total 80
-rw-rw-r-- 1 ebylmz ebylmz 7860 May 29 09:58 biboClient.c
-rw-rw-r-- 1 ebylmz ebylmz 417 May 29 09:58 biboClient.h
-rw-rw-r-- 2 ebylmz ebylmz 35677 May 29 09:58 biboServer.c
-rw-rw-r-- 1 ebylmz ebylmz 2455 May 29 09:58 biboServer.h
-rw-rw-r-- 1 ebylmz ebylmz 6068 May 29 09:58 common.c
-rw-rw-r-- 1 ebylmz ebylmz 2271 May 29 09:58 common.h
drwxrwxr-x 2 ebylmz ebylmz 4096 May 29 09:58 here
-rw-rw-r-- 1 ebylmz ebylmz 367 May 29 09:58 Makefile
-rw-rw-r-- 1 ebylmz ebylmz 3842 Jun 1 09:22 sync.c
-rw-rw-r-- 1 ebylmz ebylmz 885 May 29 09:58 sync.h

srcdir/hw04/src/here:
total 14908
-rw-rw-r-- 1 ebylmz ebylmz 252 May 29 09:58 a.c
-rw-rw-r-- 1 ebylmz ebylmz 16400 May 29 09:58 appendMeMore
-rw-rw-r-- 1 ebylmz ebylmz 4340 May 29 09:58 b.c
-rw-rw-r-- 1 ebylmz ebylmz 15000015 May 29 09:58 large.txt
-rw-rw-r-- 1 ebylmz ebylmz 194879 May 29 09:58 ne.jpg
-rw-rw-r-- 1 ebylmz ebylmz 32509 May 29 09:58 old.c

srcdir/large:
total 117216
-rw-rw-r-- 1 ebylmz ebylmz 15000015 Jun 2 16:15 a1.txt
-rw-rw-r-- 1 ebylmz ebylmz 15000015 Jun 2 16:15 a2.txt
-rw-rw-r-- 1 ebylmz ebylmz 15000015 Jun 2 16:16 a3.txt
-rw-rw-r-- 1 ebylmz ebylmz 15000015 Jun 2 16:16 a4.txt
-rw-rw-r-- 1 ebylmz ebylmz 15000015 Jun 2 16:16 a5.txt
-rw-rw-r-- 1 ebylmz ebylmz 15000015 Jun 2 16:16 a6.txt
-rw-rw-r-- 1 ebylmz ebylmz 15000015 Jun 2 16:16 a7.txt
-rw-rw-r-- 1 ebylmz ebylmz 15000015 Jun 2 16:16 a8.txt
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```


6.2 Single Source to Destination

```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src$ make run2
gcc -Mextra -Wall pCp.c util.c -o pCp
./pCp 100 10 srcdir srcdir2 dstdir
'srcdir/symlink' -> 'dstdir/symlink'
'srcdir/hardlink' -> 'dstdir/hardlink'
'srcdir/myfifo' -> 'dstdir/myfifo'
'srcdir/hw04/pCp' -> 'dstdir/hw04/pCp'
'srcdir/hw04/hw4.pdf' -> 'dstdir/hw04/hw4.pdf'
'srcdir/hw04/src/biboClient.h' -> 'dstdir/hw04/src/biboClient.h'
'srcdir/hw04/src/sync.c' -> 'dstdir/hw04/src/sync.c'
'srcdir/hw04/src/biboServer.h' -> 'dstdir/hw04/src/biboServer.h'
'srcdir/hw04/src/sync.h' -> 'dstdir/hw04/src/sync.h'
'srcdir/hw04/src/here/me.jpg' -> 'dstdir/hw04/src/here/me.jpg'
'srcdir/large/a2.txt' -> 'dstdir/large/a2.txt'
'srcdir/hw04/src/here/a.c' -> 'dstdir/hw04/src/here/a.c'
'srcdir/hw04/src/here/appendMeMore' -> 'dstdir/hw04/src/here/appendMeMore'
'srcdir/hw04/src/here/b.c' -> 'dstdir/hw04/src/here/b.c'
'srcdir/hw04/src/here/old.c' -> 'dstdir/hw04/src/here/old.c'
'srcdir/hw04/src/btboServer.c' -> 'dstdir/hw04/src/btboServer.c'
'srcdir/hw04/src/Makefile' -> 'dstdir/hw04/src/Makefile'
'srcdir/hw04/src/common.h' -> 'dstdir/hw04/src/common.h'
'srcdir/hw04/src/common.c' -> 'dstdir/hw04/src/common.c'
'srcdir/hw04/src/biboClient.c' -> 'dstdir/hw04/src/biboClient.c'
'srcdir2/report.pdf' -> 'dstdir/srcdir2/report.pdf'
'srcdir2/HW1.pdf' -> 'dstdir/srcdir2/HW1.pdf'
'srcdir2/src/verify_dup.c' -> 'dstdir/srcdir2/src/verify_dup.c'
'srcdir2/src/makefile' -> 'dstdir/srcdir2/src/makefile'
'srcdir2/src/dup.c' -> 'dstdir/srcdir2/src/dup.c'
'srcdir2/src/appendMeMore.c' -> 'dstdir/srcdir2/src/appendMeMore.c'
'srcdir/hw04/report.pdf' -> 'dstdir/hw04/report.pdf'
'srcdir/large/a8.txt' -> 'dstdir/large/a8.txt'
'srcdir/large/a3.txt' -> 'dstdir/large/a3.txt'
'srcdir/large/a5.txt' -> 'dstdir/large/a5.txt'
'srcdir/large/a4.txt' -> 'dstdir/large/a4.txt'
'srcdir/large/a1.txt' -> 'dstdir/large/a1.txt'
'srcdir/hw04/src/here/large.txt' -> 'dstdir/hw04/src/here/large.txt'
'srcdir/large/a6.txt' -> 'dstdir/large/a6.txt'
'srcdir/large/a7.txt' -> 'dstdir/large/a7.txt'

pCp STATISTICS
=====
USED SYSTEM RESOURCE
Buffer size      : 100
Worker thread pool size : 10

# OF COPIED FILES
Directory        : 5
Regular file     : 33
Symbolic link    : 1
FIFO file        : 1
Unsupported file : 0

Total transferred byte(s) : 138092831
Elapsed time           : 0.261547 seconds
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```

```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src$
pCp STATISTICS
=====
USED SYSTEM RESOURCE
Buffer size      : 100
Worker thread pool size : 10

# OF COPIED FILES
Directory        : 5
Regular file     : 33
Symbolic link    : 1
FIFO file        : 1
Unsupported file : 0

Total transferred byte(s) : 138092831
Elapsed time           : 0.261547 seconds
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$ ls -l srcdir dstdir
dstdir:
total 48
-rw-rw-r-- 1 ebylmz ebylmz 35677 Jun  2 22:52 hardlink
drwxrwxr-x 3 ebylmz ebylmz 4096 Jun  2 22:52 hw04
drwxrwxr-x 2 ebylmz ebylmz 4096 Jun  2 22:52 large
prw-rw-r-- 1 ebylmz ebylmz   0 Jun  2 22:52 myfifo
drwxrwxr-x 3 ebylmz ebylmz 4096 Jun  2 22:52 srcdir2
lrwxrwxrwx 1 ebylmz ebylmz   15 Jun  2 22:52 symlink -> hw04/src/sync.c

srcdir:
total 44
-rw-rw-r-- 2 ebylmz ebylmz 35677 May 29 09:58 hardlink
drwxrwxr-x 3 ebylmz ebylmz 4096 Jun  1 09:12 hw04
drwxrwxr-x 2 ebylmz ebylmz 4096 Jun  2 16:16 large
prw-rw-r-- 1 ebylmz ebylmz   0 May 28 21:24 myfifo
lrwxrwxrwx 1 ebylmz ebylmz   15 Jun  1 09:13 symlink -> hw04/src/sync.c
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```

6.3 Multiple Source to Destination

```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$ make run2
./pCp 100 10 srcdir srcdir2 dstdir
'srcdir/symlink' -> 'dstdir/symlink'
'srcdir/myfifo' -> 'dstdir/myfifo'
'srcdir/hardlink' -> 'dstdir/hardlink'
'srcdir/hw04/pCp' -> 'dstdir/hw04/pCp'
'srcdir/hw04/report.pdf' -> 'dstdir/hw04/report.pdf'
'srcdir/hw04/src/biboClient.h' -> 'dstdir/hw04/src/biboClient.h'
'srcdir/hw04/src/sync.c' -> 'dstdir/hw04/src/sync.c'
'srcdir/hw04/src/biboServer.h' -> 'dstdir/hw04/src/biboServer.h'
'srcdir/hw04/src/sync.h' -> 'dstdir/hw04/src/sync.h'
'srcdir/hw04/hw4.pdf' -> 'dstdir/hw04/hw4.pdf'
'srcdir/hw04/src/here/me.jpg' -> 'dstdir/hw04/src/here/me.jpg'
'srcdir/hw04/src/here/a.c' -> 'dstdir/hw04/src/here/a.c'
'srcdir/hw04/src/here/appendMeMore' -> 'dstdir/hw04/src/here/appendMeMore'
'srcdir/hw04/src/here/b.c' -> 'dstdir/hw04/src/here/b.c'
'srcdir/hw04/src/here/old.c' -> 'dstdir/hw04/src/here/old.c'
'srcdir/hw04/src/biboServer.c' -> 'dstdir/hw04/src/biboServer.c'
'srcdir/hw04/src/Makefile' -> 'dstdir/hw04/src/Makefile'
'srcdir/hw04/src/common.h' -> 'dstdir/hw04/src/common.h'
'srcdir/hw04/src/common.c' -> 'dstdir/hw04/src/common.c'
'srcdir/hw04/src/biboClient.c' -> 'dstdir/hw04/src/biboClient.c'
'srcdir2/report.pdf' -> 'dstdir/srcdir2/report.pdf'
'srcdir2/HW1.pdf' -> 'dstdir/srcdir2/HW1.pdf'
'srcdir2/src/verify_dup.c' -> 'dstdir/srcdir2/src/verify_dup.c'
'srcdir2/src/makefile' -> 'dstdir/srcdir2/src/makefile'
'srcdir2/src/dup.c' -> 'dstdir/srcdir2/src/dup.c'
'srcdir2/src/appendMeMore.c' -> 'dstdir/srcdir2/src/appendMeMore.c'
'srcdir/large/a2.txt' -> 'dstdir/large/a2.txt'
'srcdir/large/a4.txt' -> 'dstdir/large/a4.txt'
'srcdir/large/a6.txt' -> 'dstdir/large/a6.txt'
'srcdir/large/a7.txt' -> 'dstdir/large/a7.txt'
'srcdir/hw04/src/here/Large.txt' -> 'dstdir/hw04/src/here/Large.txt'
'srcdir/large/a3.txt' -> 'dstdir/large/a3.txt'
'srcdir/large/a8.txt' -> 'dstdir/large/a8.txt'
'srcdir/large/a5.txt' -> 'dstdir/large/a5.txt'
'srcdir/large/a1.txt' -> 'dstdir/large/a1.txt'

pCp STATISTICS
-----
USED SYSTEM RESOURCE
Buffer size          : 100
Worker thread pool size : 10

# OF COPIED FILES
Directory            : 5
Regular file         : 33
Symbolic link        : 1
FIFO file            : 1
Unsupported file     : 0

Total transferred byte(s) : 138092831
Elapsed time           : 0.229738 seconds
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```

```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src
pCp STATISTICS
-----
USED SYSTEM RESOURCE
Buffer size          : 100
Worker thread pool size : 10

# OF COPIED FILES
Directory            : 5
Regular file         : 33
Symbolic link        : 1
FIFO file            : 1
Unsupported file     : 0

Total transferred byte(s) : 138092831
Elapsed time           : 0.229738 seconds
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$ ls -l srcdir srcdir2 dstdir
dstdir:
total 48
-rw-rw-r-- 1 ebylmz ebylmz 35677 Jun  2 22:53 hardlink
drwxrwxr-x 3 ebylmz ebylmz 4096 Jun  2 22:53 hw04
drwxrwxr-x 2 ebylmz ebylmz 4096 Jun  2 22:53 large
prw-rw-r-- 1 ebylmz ebylmz   0 Jun  2 22:53 myfifo
drwxrwxr-x 3 ebylmz ebylmz 4096 Jun  2 22:53 srcdir2
lrwxrwxrwx 1 ebylmz ebylmz  15 Jun  2 22:53 symlink -> hw04/src/sync.c

srcdir:
total 44
-rw-rw-r-- 2 ebylmz ebylmz 35677 May 29 09:58 hardlink
drwxrwxr-x 3 ebylmz ebylmz 4096 Jun  1 09:12 hw04
drwxrwxr-x 2 ebylmz ebylmz 4096 Jun  2 16:16 large
prw-rw-r-- 1 ebylmz ebylmz   0 May 28 21:24 myfifo
lrwxrwxrwx 1 ebylmz ebylmz  15 Jun  1 09:13 symlink -> hw04/src/sync.c

srcdir2:
total 792
-rw-rw-r-- 1 ebylmz ebylmz 34810 Jun  1 12:32 HW1.pdf
-rw-rw-r-- 1 ebylmz ebylmz 769869 Jun  1 12:32 report.pdf
drwxrwxr-x 2 ebylmz ebylmz 4096 Jun  1 12:32 src
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```

6.4 Signal Handling

```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src x ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src x v
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$ ./pCp 10000 1001 srcdir dstdir
'srcdir/symlink' -> 'dstdir/srcdir/symlink'
'srcdir/hardlink' -> 'dstdir/srcdir/hardlink'
'srcdir/large/a2.txt' -> 'dstdir/srcdir/large/large/a2.txt'
'^C'srcdir/large/a8.txt' -> 'dstdir/srcdir/large/large/a8.txt'

SIGNAL caught during copy 'srcdir/hw04' -> 'dstdir/srcdir/hw04/hw04'
'srcdir/large/a1.txt' -> 'dstdir/srcdir/large/large/a1.txt'

SIGNAL caught during copy 'srcdir' -> 'dstdir/srcdir'

SIGNAL caught
'srcdir/large/a6.txt' -> 'dstdir/srcdir/large/large/a6.txt'
'srcdir/large/a5.txt' -> 'dstdir/srcdir/large/large/a5.txt'
'srcdir/large/a7.txt' -> 'dstdir/srcdir/large/large/a7.txt'
'srcdir/large/a4.txt' -> 'dstdir/srcdir/large/large/a4.txt'
'srcdir/large/a3.txt' -> 'dstdir/srcdir/large/large/a3.txt'

pCp STATISTICS
~~~~~
USED SYSTEM RESOURCE
Buffer size      : 10000
Worker thread pool size : 1001

# OF COPIED FILES
Directory       : 2
Regular file    : 9
Symbolic link   : 1
FIFO file       : 0
Unsupported file : 0

Total transferred byte(s) : 120035797
Elapsed time          : 0.300460 seconds
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```

Signal is cached, the copy operation is stopped, and exited gracefully.

6.5 Memory Leak Check

```
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src
ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src x ebylmz@ebylmz: ~/cse/System-Programming/hw/hw05/src x v
'srcdir/large/a6.txt' -> 'dstdir/large/a6.txt'
'srcdir/large/a3.txt' -> 'dstdir/large/a3.txt'
'srcdir/large/a8.txt' -> 'dstdir/large/a8.txt'
'srcdir/large/a4.txt' -> 'dstdir/large/a4.txt'
'srcdir/large/a7.txt' -> 'dstdir/large/a7.txt'
'srcdir/large/a5.txt' -> 'dstdir/large/a5.txt'
'srcdir/large/a2.txt' -> 'dstdir/large/a2.txt'
'srcdir/large/a1.txt' -> 'dstdir/large/a1.txt'
'srcdir/hw04/src/here/large.txt' -> 'dstdir/hw04/src/here/large.txt'

pCp STATISTICS
~~~~~
USED SYSTEM RESOURCE
Buffer size      : 100
Worker thread pool size : 10

# OF COPIED FILES
Directory       : 4
Regular file    : 27
Symbolic link   : 1
FIFO file       : 1
Unsupported file : 0

Total transferred byte(s) : 137276658
Elapsed time          : 7.844542 seconds
==272394==
==272394== HEAP SUMMARY:
==272394==   in use at exit: 0 bytes in 0 blocks
==272394== total heap usage: 133 allocs, 133 frees, 363,660 bytes allocated
==272394==
==272394== All heap blocks were freed -- no leaks are possible
==272394==
==272394== ERROR SUMMARY: 0 errors from 0 contexts (suppressed: 0 from 0)
ebylmz@ebylmz:~/cse/System-Programming/hw/hw05/src$
```