Московский Авиационный Институт

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Институт №8 “Компьютерные науки и прикладная математика”

Кафедра №806 “Вычислительная математика и программирование”

Лабораторная работа №1 по курсу

«Операционные системы»

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Оценка: _____

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Постановка задачи

Вариант 14.

Разработать программу-родитель, которая создает два дочерних процесса. Взаимодействие между процессами организуется через неименованные каналы (pipes). Первый дочерний процесс (child1) должен преобразовывать все символы входной строки в нижний регистр, а второй дочерний процесс (child2) должен удалять все подряд идущие пробелы, оставляя только одиночные пробелы. Родительский процесс читает строки из стандартного ввода, передает их через цепочку процессов и выводит окончательный результат.

Общий метод и алгоритм решения

- id_t fork(void); — создает дочерний процесс
- int pipe(int fd[2]); — создает неименованный канал
- ssize_t read(int fd, void *buf, size_t count); — чтение из файлового дескриптора
- ssize_t write(int fd, const void *buf, size_t count); — запись в файловый дескриптор
- int dup2(int oldfd, int newfd); — перенаправление стандартных потоков
- int execl(const char *path, const char *arg, ...); — запуск исполняемого файла
- pid_t waitpid(pid_t pid, int *status, int options); — ожидание завершения процесса

Алгоритм работы программы:

1. **Инициализация каналов**: Родительский процесс создает три канала:
   - pipe1: родитель → child1
   - pipe2: child1 → child2
   - pipe3: child2 → родитель
2. **Создание процессов**: Родитель создает два дочерних процесса с помощью fork()
3. **Настройка дочерних процессов**:
   - Child1: перенаправляет stdin на pipe1, stdout на pipe2, выполняет программу child1
   - Child2: перенаправляет stdin на pipe2, stdout на pipe3, выполняет программу child2
4. **Обработка данных**:
   - Родитель читает строки из stdin и пишет в pipe1
   - Child1 читает из pipe1, переводит в нижний регистр, пишет в pipe2
   - Child2 читает из pipe2, удаляет лишние пробелы, пишет в pipe3
   - Родитель читает из pipe3 и выводит результат
5. **Завершение**: При окончании ввода родитель закрывает каналы и ожидает завершения дочерних процессов

Код программы

parent.c

```
#define _GNU_SOURCE
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
```

```c
#include <sys/wait.h>
#include <string.h>
#include <errno.h>

#define BUF 4096

ssize_t write_all(int fd, const void *buf, size_t count) {
    const char *p = buf;
    size_t left = count;
    while (left > 0) {
        ssize_t n = write(fd, p, left);
        if (n < 0) {
            if (errno == EINTR) continue;
            return -1;
        }
        left -= n;
        p += n;
    }
    return count;
}

ssize_t read_line(int fd, char *buf, size_t cap) {
    size_t pos = 0;
    while (pos + 1 < cap) {
        char c;
        ssize_t n = read(fd, &c, 1);
        if (n <= 0) break;
        buf[pos++] = c;
        if (c == '\n') break;
    }
    buf[pos] = '\0';
    return pos;
}

int main() {
    int p1[2], p2[2], p3[2];

    if (pipe(p1) == -1 || pipe(p2) == -1 || pipe(p3) == -1) {
        perror("pipe");
        exit(1);
    }

    pid_t c1 = fork();
    if (c1 == 0) {
        dup2(p1[0], STDIN_FILENO);
        dup2(p2[1], STDOUT_FILENO);

        close(p1[0]); close(p1[1]);
        close(p2[0]); close(p2[1]);
        close(p3[0]); close(p3[1]);

        execl("./child1", "child1", NULL);
        perror("exec child1");
        _exit(1);
    }

    pid_t c2 = fork();
    if (c2 == 0) {
        dup2(p2[0], STDIN_FILENO);
        dup2(p3[1], STDOUT_FILENO);

        close(p1[0]); close(p1[1]);
        close(p2[0]); close(p2[1]);
        close(p3[0]); close(p3[1]);
```

```
        execl("./child2", "child2", NULL);
        perror("exec child2");
        _exit(1);
    }

    close(p1[0]);
    close(p2[0]); close(p2[1]);
    close(p3[1]);

    char line[BUF], result[BUF];
    printf("Введите строку:\n");

    while (fgets(line, sizeof(line), stdin)) {
        write_all(p1[1], line, strlen(line));

        ssize_t n = read_line(p3[0], result, sizeof(result));
        if (n <= 0) break;

        printf("Результат: %s", result);
    }

    close(p1[1]);
    close(p3[0]);
    waitpid(c1, NULL, 0);
    waitpid(c2, NULL, 0);

    return 0;
}
```

child1.c

```
#include <stdio.h>
#include <unistd.h>
#include <ctype.h>

int main() {
    char buf[4096];
    ssize_t n;

    while ((n = read(STDIN_FILENO, buf, sizeof(buf))) > 0) {
        for (ssize_t i = 0; i < n; i++) {
            buf[i] = tolower((unsigned char)buf[i]);
        }
        write(STDOUT_FILENO, buf, n);
    }
    return 0;
}
```

child2.c

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

int main() {
    char in[4096], out[4096];
    ssize_t n;
    int last_space = 0;

    while ((n = read(STDIN_FILENO, in, sizeof(in))) > 0) {
        ssize_t pos = 0;

        for (ssize_t i = 0; i < n; i++) {
            if (in[i] == ' ') {
                if (!last_space) {
                    out[pos++] = ' ';
                }
                last_space = 1;
```

```
            } else {
                out[pos++] = in[i];
                last_space = 0;
            }
        }
        write(STDOUT_FILENO, out, pos);
    }
    return 0;
}
```

Протокол работы программы

```
on@DESKTOP-F8Q4L97:/mnt/c/Users/Son/LabsOS$ ./parent
Введите строку:
HELLO  WORLD! hELLo  WoRLD!
hello world! hello world!
```

Strace:

```
436   execve("./parent", ["./parent"], 0x7ffd796dc3c8 /* 25 vars */) = 0
436   brk(NULL)                         = 0x6407c586a000
436   mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7b239c26b000
436   access("/etc/ld.so.preload", R_OK) = -1 ENOENT (No such file or directory)
436   openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
436   fstat(3, {st_mode=S_IFREG|0644, st_size=52259, ...}) = 0
436   mmap(NULL, 52259, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7b239c25e000
436   close(3)                          = 0
436   openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
436   read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\220\243\2\0\0\0\0\0"...,
832) = 832
436   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
436   fstat(3, {st_mode=S_IFREG|0755, st_size=2125328, ...}) = 0
436   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
436   mmap(NULL, 2170256, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0) = 0x7b239c000000
436   mmap(0x7b239c028000, 1605632, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x28000) = 0x7b239c028000
436   mmap(0x7b239c1b0000, 323584, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1b0000) = 0x7b239c1b0000
436   mmap(0x7b239c1ff000, 24576, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1fe000) = 0x7b239c1ff000
436   mmap(0x7b239c205000, 52624, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0) = 0x7b239c205000
436   close(3)                          = 0
436   mmap(NULL, 12288, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) =
0x7b239c25b000
436   arch_prctl(ARCH_SET_FS, 0x7b239c25b740) = 0
436   set_tid_address(0x7b239c25ba10)   = 436
436   set_robust_list(0x7b239c25ba20, 24) = 0
436   rseq(0x7b239c25c060, 0x20, 0, 0x53053053) = 0
436   mprotect(0x7b239c1ff000, 16384, PROT_READ) = 0
436   mprotect(0x6407b87e4000, 4096, PROT_READ) = 0
436   mprotect(0x7b239c2a3000, 8192, PROT_READ) = 0
436   prlimit64(0, RLIMIT_STACK, NULL, {rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY})
= 0
436   munmap(0x7b239c25e000, 52259)     = 0
436   pipe2([3, 4], 0)                  = 0
436   pipe2([5, 6], 0)                  = 0
436   pipe2([7, 8], 0)                  = 0
436   clone(child_stack=NULL, flags=CLONE_CHILD_CLEARTID|CLONE_CHILD_SETTID|SIGCHLD,
child_tidptr=0x7b239c25ba10) = 437
437   set_robust_list(0x7b239c25ba20, 24 <unfinished ...>
```

```
     436   clone(child_stack=NULL, flags=CLONE_CHILD_CLEARTID|CLONE_CHILD_SETTID|SIGCHLD
<unfinished ...>
     437   <... set_robust_list resumed>)    = 0
     436   <... clone resumed>, child_tidptr=0x7b239c25ba10) = 438
     437   dup2(3, 0 <unfinished ...>
     436   close(3 <unfinished ...>
     438   set_robust_list(0x7b239c25ba20, 24 <unfinished ...>
     436   <... close resumed>)              = 0
     437   <... dup2 resumed>)               = 0
     436   close(5 <unfinished ...>
     438   <... set_robust_list resumed>)    = 0
     436   <... close resumed>)              = 0
     437   dup2(6, 1 <unfinished ...>
     436   close(6 <unfinished ...>
     438   dup2(5, 0 <unfinished ...>
     436   <... close resumed>)              = 0
     437   <... dup2 resumed>)               = 1
     436   close(8 <unfinished ...>
     438   <... dup2 resumed>)               = 0
     436   <... close resumed>)              = 0
     437   close(3 <unfinished ...>
     436   fstat(1,  <unfinished ...>
     438   dup2(8, 1 <unfinished ...>
     436   <... fstat resumed>{st_mode=S_IFCHR|0620, st_rdev=makedev(0x88, 0), ...}) = 0
     437   <... close resumed>)              = 0
     436   getrandom( <unfinished ...>
     438   <... dup2 resumed>)               = 1
     436   <... getrandom resumed>"\xbf\x43\xa4\xc9\xe3\xd4\x75\xc2", 8, GRND_NONBLOCK) = 8
     437   close(4 <unfinished ...>
     436   brk(NULL <unfinished ...>
     438   close(3 <unfinished ...>
     436   <... brk resumed>)                = 0x6407c586a000
     437   <... close resumed>)              = 0
     436   brk(0x6407c588b000 <unfinished ...>
     438   <... close resumed>)              = 0
     436   <... brk resumed>)                = 0x6407c588b000
     437   close(5 <unfinished ...>
     436   write(1, "\320\222\320\262\320\265\320\264\320\270\321\202\320\265
\321\201\321\202\321\200\320\276\320\272\321\203:\n", 29 <unfinished ...>
     438   close(4 <unfinished ...>
     436   <... write resumed>)              = 29
     437   <... close resumed>)              = 0
     436   fstat(0,  <unfinished ...>
     438   <... close resumed>)              = 0
     436   <... fstat resumed>{st_mode=S_IFCHR|0620, st_rdev=makedev(0x88, 0), ...}) = 0
     437   close(6 <unfinished ...>
     436   read(0,  <unfinished ...>
     438   close(5 <unfinished ...>
     437   <... close resumed>)              = 0
     438   <... close resumed>)              = 0
     437   close(7 <unfinished ...>
     438   close(6 <unfinished ...>
     437   <... close resumed>)              = 0
     438   <... close resumed>)              = 0
     437   close(8 <unfinished ...>
     438   close(7 <unfinished ...>
     437   <... close resumed>)              = 0
     438   <... close resumed>)              = 0
     437   execve("./child1", ["child1"], 0x7fff0d3f0a98 /* 25 vars */ <unfinished ...>
     438   close(8)                          = 0
     438   execve("./child2", ["child2"], 0x7fff0d3f0a98 /* 25 vars */) = 0
     438   brk(NULL <unfinished ...>
     437   <... execve resumed>)             = 0
     438   <... brk resumed>)                = 0x5b4ad6732000
     437   brk(NULL <unfinished ...>
```

```
     438   mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0
<unfinished ...>
     437   <... brk resumed>)                = 0x56f2cacea000
     438   <... mmap resumed>)               = 0x7fc0814c4000
     437   mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0
<unfinished ...>
     438   access("/etc/ld.so.preload", R_OK <unfinished ...>
     437   <... mmap resumed>)               = 0x704d8bdd4000
     438   <... access resumed>)             = -1 ENOENT (No such file or directory)
     437   access("/etc/ld.so.preload", R_OK <unfinished ...>
     438   openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC <unfinished ...>
     437   <... access resumed>)             = -1 ENOENT (No such file or directory)
     438   <... openat resumed>)             = 3
     437   openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC <unfinished ...>
     438   fstat(3,  <unfinished ...>
     437   <... openat resumed>)             = 3
     438   <... fstat resumed>{st_mode=S_IFREG|0644, st_size=52259, ...}) = 0
     437   fstat(3,  <unfinished ...>
     438   mmap(NULL, 52259, PROT_READ, MAP_PRIVATE, 3, 0 <unfinished ...>
     437   <... fstat resumed>{st_mode=S_IFREG|0644, st_size=52259, ...}) = 0
     438   <... mmap resumed>)               = 0x7fc0814b7000
     437   mmap(NULL, 52259, PROT_READ, MAP_PRIVATE, 3, 0 <unfinished ...>
     438   close(3 <unfinished ...>
     437   <... mmap resumed>)               = 0x704d8bdc7000
     438   <... close resumed>)              = 0
     437   close(3 <unfinished ...>
     438   openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC
<unfinished ...>
     437   <... close resumed>)              = 0
     438   <... openat resumed>)             = 3
     437   openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC
<unfinished ...>
     438   read(3,  <unfinished ...>
     437   <... openat resumed>)             = 3
     438   <... read
resumed>"\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\220\243\2\0\0\0\0"..., 832) = 832
     437   read(3,  <unfinished ...>
     438   pread64(3,  <unfinished ...>
     437   <... read
resumed>"\177ELF\2\1\1\3\0\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\220\243\2\0\0\0\0"..., 832) = 832
     438   <... pread64
resumed>"\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
     437   pread64(3,  <unfinished ...>
     438   fstat(3,  <unfinished ...>
     437   <... pread64
resumed>"\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
     438   <... fstat resumed>{st_mode=S_IFREG|0755, st_size=2125328, ...}) = 0
     437   fstat(3,  <unfinished ...>
     438   pread64(3,  <unfinished ...>
     437   <... fstat resumed>{st_mode=S_IFREG|0755, st_size=2125328, ...}) = 0
     438   <... pread64
resumed>"\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
     437   pread64(3,  <unfinished ...>
     438   mmap(NULL, 2170256, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0 <unfinished ...>
     437   <... pread64
resumed>"\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
     438   <... mmap resumed>)               = 0x7fc081200000
     437   mmap(NULL, 2170256, PROT_READ, MAP_PRIVATE|MAP_DENYWRITE, 3, 0 <unfinished ...>
     438   mmap(0x7fc081228000, 1605632, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x28000 <unfinished ...>
     437   <... mmap resumed>)               = 0x704d8ba00000
     438   <... mmap resumed>)               = 0x7fc081228000
     437   mmap(0x704d8ba28000, 1605632, PROT_READ|PROT_EXEC,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x28000 <unfinished ...>
```

```
     438   mmap(0x7fc0813b0000, 323584, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1b0000 <unfinished ...>
     437   <... mmap resumed>)               = 0x704d8ba28000
     438   <... mmap resumed>)               = 0x7fc0813b0000
     437   mmap(0x704d8bbb0000, 323584, PROT_READ, MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3,
0x1b0000 <unfinished ...>
     438   mmap(0x7fc0813ff000, 24576, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1fe000 <unfinished ...>
     437   <... mmap resumed>)               = 0x704d8bbb0000
     438   <... mmap resumed>)               = 0x7fc0813ff000
     437   mmap(0x704d8bbff000, 24576, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_DENYWRITE, 3, 0x1fe000 <unfinished ...>
     438   mmap(0x7fc081405000, 52624, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0 <unfinished ...>
     437   <... mmap resumed>)               = 0x704d8bbff000
     438   <... mmap resumed>)               = 0x7fc081405000
     437   mmap(0x704d8bc05000, 52624, PROT_READ|PROT_WRITE,
MAP_PRIVATE|MAP_FIXED|MAP_ANONYMOUS, -1, 0 <unfinished ...>
     438   close(3 <unfinished ...>
     437   <... mmap resumed>)               = 0x704d8bc05000
     438   <... close resumed>)              = 0
     437   close(3 <unfinished ...>
     438   mmap(NULL, 12288, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0
<unfinished ...>
     437   <... close resumed>)              = 0
     438   <... mmap resumed>)               = 0x7fc0814b4000
     437   mmap(NULL, 12288, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0
<unfinished ...>
     438   arch_prctl(ARCH_SET_FS, 0x7fc0814b4740 <unfinished ...>
     437   <... mmap resumed>)               = 0x704d8bdc4000
     438   <... arch_prctl resumed>)         = 0
     437   arch_prctl(ARCH_SET_FS, 0x704d8bdc4740 <unfinished ...>
     438   set_tid_address(0x7fc0814b4a10 <unfinished ...>
     437   <... arch_prctl resumed>)         = 0
     438   <... set_tid_address resumed>)    = 438
     437   set_tid_address(0x704d8bdc4a10 <unfinished ...>
     438   set_robust_list(0x7fc0814b4a20, 24 <unfinished ...>
     437   <... set_tid_address resumed>)    = 437
     438   <... set_robust_list resumed>)    = 0
     437   set_robust_list(0x704d8bdc4a20, 24 <unfinished ...>
     438   rseq(0x7fc0814b5060, 0x20, 0, 0x53053053 <unfinished ...>
     437   <... set_robust_list resumed>)    = 0
     438   <... rseq resumed>)               = 0
     437   rseq(0x704d8bdc5060, 0x20, 0, 0x53053053 <unfinished ...>
     438   mprotect(0x7fc0813ff000, 16384, PROT_READ <unfinished ...>
     437   <... rseq resumed>)               = 0
     438   <... mprotect resumed>)           = 0
     437   mprotect(0x704d8bbff000, 16384, PROT_READ <unfinished ...>
     438   mprotect(0x5b4ac3130000, 4096, PROT_READ <unfinished ...>
     437   <... mprotect resumed>)           = 0
     438   <... mprotect resumed>)           = 0
     437   mprotect(0x56f292c42000, 4096, PROT_READ <unfinished ...>
     438   mprotect(0x7fc0814fc000, 8192, PROT_READ <unfinished ...>
     437   <... mprotect resumed>)           = 0
     438   <... mprotect resumed>)           = 0
     437   mprotect(0x704d8be0c000, 8192, PROT_READ <unfinished ...>
     438   prlimit64(0, RLIMIT_STACK, NULL,  <unfinished ...>
     437   <... mprotect resumed>)           = 0
     438   <... prlimit64 resumed>{rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}) = 0
     437   prlimit64(0, RLIMIT_STACK, NULL,  <unfinished ...>
     438   munmap(0x7fc0814b7000, 52259 <unfinished ...>
     437   <... prlimit64 resumed>{rlim_cur=8192*1024, rlim_max=RLIM64_INFINITY}) = 0
     438   <... munmap resumed>)             = 0
     437   munmap(0x704d8bdc7000, 52259 <unfinished ...>
     438   read(0,  <unfinished ...>
```

```
     437   <... munmap resumed>)             = 0
     437   read(0,  <unfinished ...>
     436   <... read resumed>"HELLO  WORLD! hELLo  WoRLD!\n", 1024) = 28
     436   write(4, "HELLO  WORLD! hELLo  WoRLD!\n", 28) = 28
     437   <... read resumed>"HELLO  WORLD! hELLo  WoRLD!\n", 4096) = 28
     436   read(7,  <unfinished ...>
     437   write(1, "hello  world! hello  world!\n", 28 <unfinished ...>
     438   <... read resumed>"hello  world! hello  world!\n", 4096) = 28
     437   <... write resumed>)              = 28
     438   write(1, "hello world! hello world!\n", 26 <unfinished ...>
     437   read(0,  <unfinished ...>
     436   <... read resumed>"h", 1)         = 1
     438   <... write resumed>)              = 26
     436   read(7,  <unfinished ...>
     438   read(0,  <unfinished ...>
     436   <... read resumed>"e", 1)         = 1
     436   read(7, "l", 1)                   = 1
     436   read(7, "l", 1)                   = 1
     436   read(7, "o", 1)                   = 1
     436   read(7, " ", 1)                   = 1
     436   read(7, "w", 1)                   = 1
     436   read(7, "o", 1)                   = 1
     436   read(7, "r", 1)                   = 1
     436   read(7, "l", 1)                   = 1
     436   read(7, "d", 1)                   = 1
     436   read(7, "!", 1)                   = 1
     436   read(7, " ", 1)                   = 1
     436   read(7, "h", 1)                   = 1
     436   read(7, "e", 1)                   = 1
     436   read(7, "l", 1)                   = 1
     436   read(7, "l", 1)                   = 1
     436   read(7, "o", 1)                   = 1
     436   read(7, " ", 1)                   = 1
     436   read(7, "w", 1)                   = 1
     436   read(7, "o", 1)                   = 1
     436   read(7, "r", 1)                   = 1
     436   read(7, "l", 1)                   = 1
     436   read(7, "d", 1)                   = 1
     436   read(7, "!", 1)                   = 1
     436   read(7, "\n", 1)                  = 1
     436   write(1, "hello world! hello world!\n", 26) = 26
     436   read(0, "", 1024)                 = 0
     436   close(4)                          = 0
     437   <... read resumed>"", 4096)       = 0
     436   close(7 <unfinished ...>
     437   exit_group(0 <unfinished ...>
     436   <... close resumed>)              = 0
     437   <... exit_group resumed>)         = ?
     436   wait4(437,  <unfinished ...>
     438   <... read resumed>"", 4096)       = 0
     437   +++ exited with 0 +++
     436   <... wait4 resumed>NULL, 0, NULL) = 437
     438   exit_group(0 <unfinished ...>
     436   --- SIGCHLD {si_signo=SIGCHLD, si_code=CLD_EXITED, si_pid=437, si_uid=1000,
si_status=0, si_utime=0, si_stime=0} ---
     438   <... exit_group resumed>)         = ?
     436   wait4(438,  <unfinished ...>
     438   +++ exited with 0 +++
     436   <... wait4 resumed>NULL, 0, NULL) = 438
     436   --- SIGCHLD {si_signo=SIGCHLD, si_code=CLD_EXITED, si_pid=438, si_uid=1000,
si_status=0, si_utime=0, si_stime=0} ---
     436   exit_group(0)                     = ?
     436   +++ exited with 0 +++
```

Вывод

В ходе лабораторной работы была успешно реализована система взаимодействующих процессов через неименованные каналы. Программа корректно выполняет двухэтапную обработку текста: перевод в нижний регистр и удаление лишних пробелов. Основные трудности были связаны с правильным управлением файловыми дескрипторами и организацией передачи данных между процессами. Полученный опыт демонстрирует эффективность межпроцессного взаимодействия в UNIX-системах.