Operating Systems Spring Semester
Dr. HEEKUCK OH

Operating Systems Project 3
The Reader Writer Problem

—

By HONGGEUN JI [2019042633], Division of Computer Science, HYU ERICA

14.05.21

Introduction

This report is about the third assignment given by Dr. HEEKUCK OH. The assignment was to understand the problems of synchronization and provide appropriate solutions. The reader preference problem is already dealt with in the lab. This report will only focus on the writer-preference and fair-reader-writer problem.

By using the POSIX synchronization, we can solve this preference problem and can fully understand the synchronization concept.

How does it work? - The Writer Preference

1. **The Mutex “r_avail”**
   This *“r_avail”* mutex will be used to compete between readers and writers. As writers should precede the readers even if the writers arrive later, the first writer lock this mutex (get this mutex) to precede the other readers. The readers should get the *“r_avil”* mutex later and this leads the readers to wait until the last writer unlocks this mutex.

2. **The Mutex “r_mutex” and “w_mutex”**
   Both readers and writers should count themselves to choose when to lock or unlock the *"rw_mutex"*. However, counting should happen one at a time, and this means no overlap among the readers or writers. To do this, *“r_mutex”* and *“w_mutex”* will be used when they have to count up or down their number.

3. **The Mutex “rw_mutex”**
   The shared mutex when readers or writers run themselves. As the runner can overlap with other runners, only the first runner locks this mutex, and let the last mutex unlocks it. However, writers cannot overlap not only with the readers but also other writers. In this regard, the *“rw_mutex”* will be used all the time whenever the writer wants to run itself.

Codes - The Writer Preference

```
/*
 * Copyright 2020, 2021. Heekuck Oh, all rights reserved
 * 이 프로그램은 한양대학교 ERICA 소프트웨어학부 재학생을 위한 교육용으로 제작되었습니다.
 */
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#include <pthread.h>
#include <unistd.h>
#include <fcntl.h>

#define N 8192
#define L1 75
#define L2 70
#define L3 70
#define RNUM 10
#define WNUM 3

/*
 ...
 ...
 face picture with a number of chars...
 ...
 */

/*
 * alive 값이 1이면 각 스레드는 무한 루프를 돌며 반복해서 일을 하고,
 * alive 값이 0이 되면 무한 루프를 빠져나와 스레드를 자연스럽게 종료한다.
 */

int alive = 1;
pthread_mutex_t rw_mutex;
pthread_mutex_t r_mutex;
pthread_mutex_t r_avail;
pthread_mutex_t w_mutex;
int r_cnt = 0;
int w_cnt = 0;
/*
 * Reader 스레드는 같은 문자를 N번 출력한다. 예를 들면 <AAA...AA> 이런 식이다.
 * 출력할 문자는 인자를 통해 0이면 A, 1이면 B, ..., 등으로 출력하며, 시작과 끝을 <...>로 나타낸다.
 * 단일 reader라면 <AAA...AA>처럼 같은 문자만 출력하겠지만, critical section에서 reader의
 * 중복을 허용하기 때문에 reader가 많아지면 출력이 어지럽게 섞여서 나오는 것이 정상이다.
 */
void *reader(void *arg)
{
```

```
    int id, i;

    /*
     * 들어온 인자를 통해 출력할 문자의 종류를 정한다.
     */
    id = *(int *)arg;

    /*
    * 스레드가 살아 있는 동안 같은 문자열 시퀀스 <XXX...XX>를 반복해서 출력한다.
    */
    while (alive) {
        pthread_mutex_lock(&r_avail);   // reader available when writer allows
            pthread_mutex_lock(&r_mutex);   // r_cnt cannot be accessed at the same
        if(++r_cnt == 1) pthread_mutex_lock(&rw_mutex);   // first reader get rw_mutex for others
            pthread_mutex_unlock(&r_mutex);
        pthread_mutex_unlock(&r_avail);

        /*
         * Begin Critical Section
         */
        printf("<");
         for (i = 0; i < N; ++i)
            printf("%c", 'A'+id);
         printf(">");
         /*
         * End Critical Section
         */

        pthread_mutex_lock(&r_mutex);
        if(--r_cnt == 0)
            pthread_mutex_unlock(&rw_mutex);
        pthread_mutex_unlock(&r_mutex);
    }
    pthread_exit(0);
}

/*
 * Writer 스레드는 어떤 사람의 얼굴 이미지를 출력한다.
 * 이미지는 세 가지 종류가 있으며 인자를 통해 식별한다.
 * Writer가 critical section에 있으면 다른 writer는 물론이고 어떠한 reader도 들어올 수 없다.
 * 만일 이것을 어기고 다른 writer나 reader가 들어왔다면 얼굴 이미지가 깨져서 쉽게 감지된다.
 */
void *writer(void *arg)
{
    int id, i;
    struct timespec req, rem;

    /*
    * 들어온 인자를 통해 얼굴 이미지의 종류를 정한다.
```

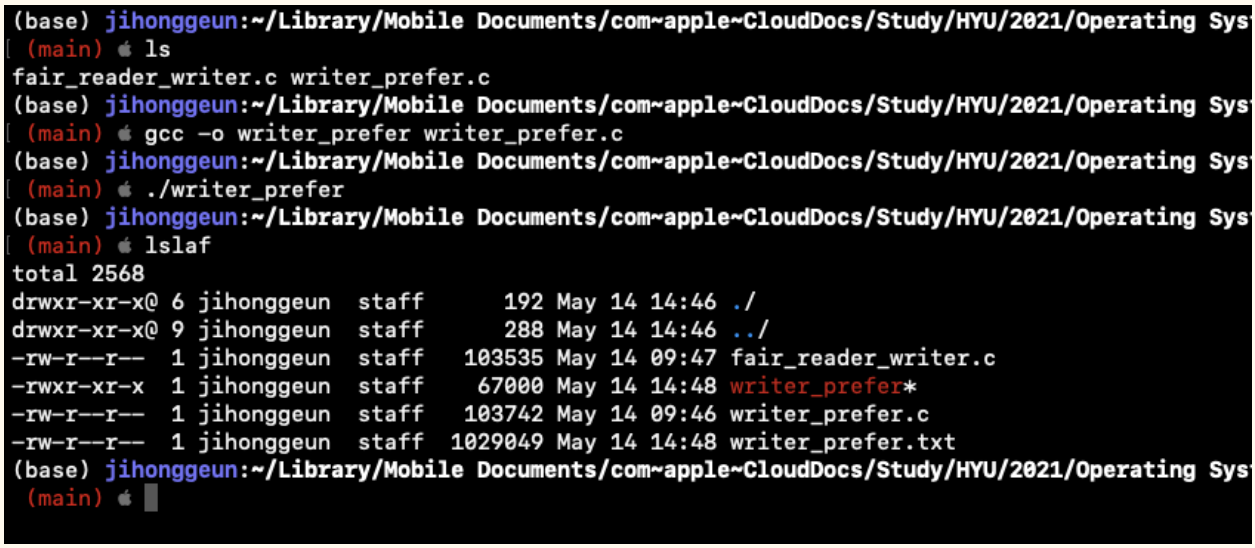
```
*/
id = *(int *)arg;
/*
* 이미지 출력을 천천히 하기 위해 한 줄 출력할 때마다 쉬는 시간을 1 나노초로 설정한다.
*/
req.tv_sec = 0;
req.tv_nsec = 1L;
/*
* 스레드가 살아 있는 동안 같은 이미지를 반복해서 출력한다.
*/
while (alive) {
	pthread_mutex_lock(&w_mutex);	// w_cnt cannot be accessed at the same
	if(++w_cnt == 1) pthread_mutex_lock(&r_avail);	// first writer suspends readers
	pthread_mutex_unlock(&w_mutex);

	pthread_mutex_lock(&rw_mutex);	// writers cannot overlap each other

	/*
	 * Begin Critical Section
	 */
	printf("\n");
	switch (id) {
		case 0:
			for (i = 0; i < L1; ++i) {
				printf("%s\n", t[i]);
				nanosleep(&req, &rem);
			}
			break;
		case 1:
			for (i = 0; i < L2; ++i) {
				printf("%s\n", d[i]);
				nanosleep(&req, &rem);
			}
			break;
		case 2:
			for (i = 0; i < L3; ++i) {
				printf("%s\n", e[i]);
				nanosleep(&req, &rem);
			}
			break;
		default:
			;
	}
	/*
	 * End Critical Section
	 */

	pthread_mutex_unlock(&rw_mutex);
```

```
            pthread_mutex_lock(&w_mutex);
            if(--w_cnt == 0) pthread_mutex_unlock(&r_avail);   // last writer allows the readers come in CS
            pthread_mutex_unlock(&w_mutex);

        }
    pthread_exit(0);
}

/*
 * 메인 함수는 RNUM 개의 reader 스레드를 생성하고, WNUM 개의 writer 스레드를 생성한다.
 * 생성된 스레드가 일을 할 동안 0.2초 동안 기다렸다가 alive의 값을 0으로 바꿔서 모든 스레드가
 * 무한 루프를 빠져나올 수 있게 만든 후, 스레드가 자연스럽게 종료할 때까지 기다리고 메인을 종료한다.
 */
int main(void)
{
    int i;
    int rarg[RNUM], warg[WNUM];
    pthread_t rthid[RNUM];
    pthread_t wthid[WNUM];
    struct timespec req, rem;

    // stdout is now the txt file
    int output_fd = open("writer_prefer.txt", O_CREAT|O_TRUNC|O_RDWR, 0666);
    dup2(output_fd, STDOUT_FILENO);

    pthread_mutex_init(&rw_mutex, NULL);
    pthread_mutex_init(&r_mutex, NULL);
    pthread_mutex_init(&r_avail, NULL);
    pthread_mutex_init(&w_mutex, NULL);

    /*
     * Create RNUM reader threads
     */
    for (i = 0; i < RNUM; ++i) {
        rarg[i] = i;
          if (pthread_create(rthid+i, NULL, reader, rarg+i) != 0) {
              fprintf(stderr, "pthread_create error\n");
              exit(-1);
          }
    }
    /*
     * Create WNUM writer threads
     */
    for (i = 0; i < WNUM; ++i) {
        warg[i] = i;
        if (pthread_create(wthid+i, NULL, writer, warg+i) != 0) {
            fprintf(stderr, "pthread_create error\n");
            exit(-1);
        }
```

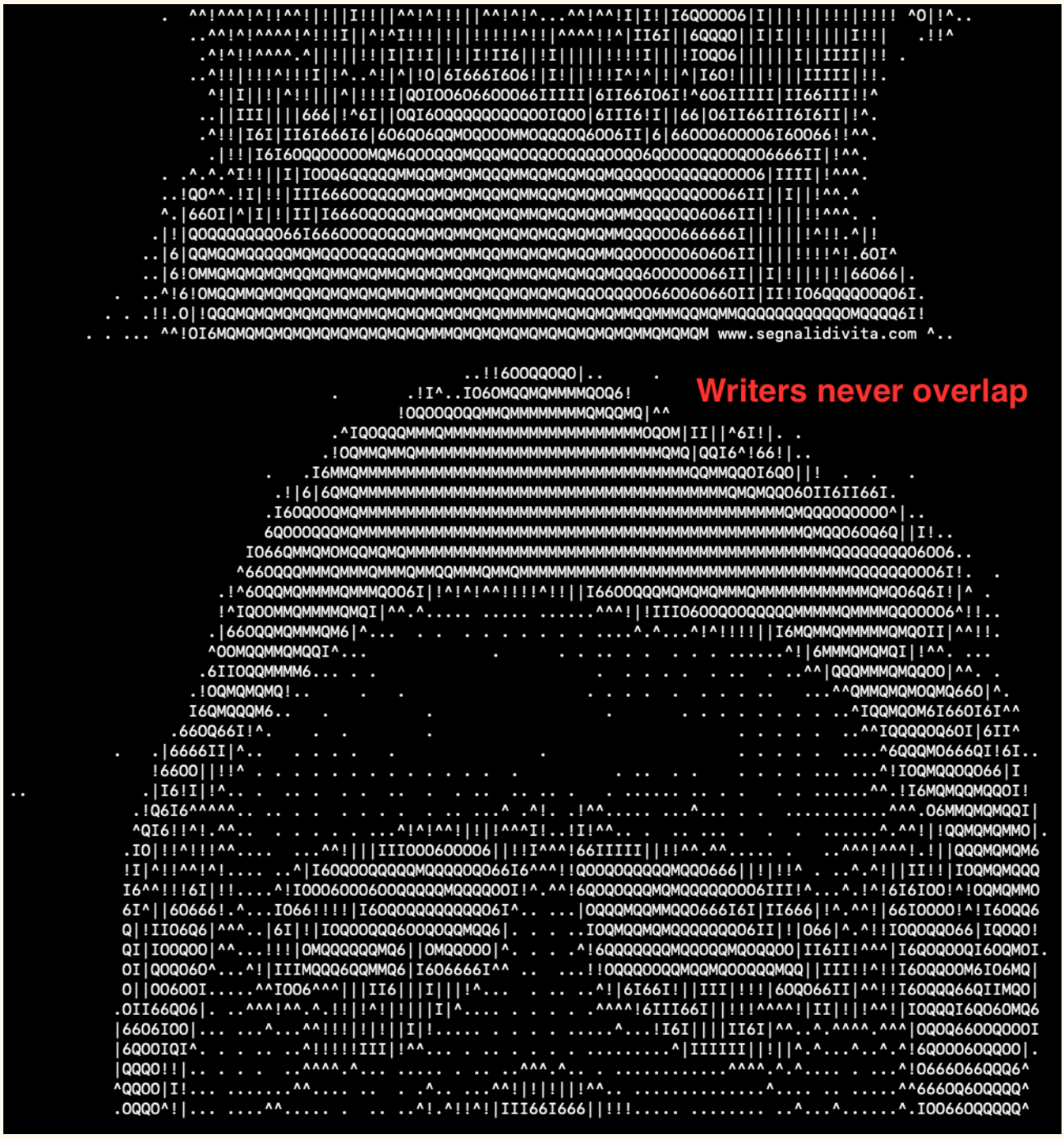
```
    }
    /*
     * Wait for 0.2 second while the threads are working
     */
    req.tv_sec = 0;
    req.tv_nsec = 200000000L;
    nanosleep(&req, &rem);
    /*
     * Now terminate all threads and leave
     */
    alive = 0;
    for (i = 0; i < RNUM; ++i)
        pthread_join(rthid[i], NULL);
    for (i = 0; i < WNUM; ++i)
        pthread_join(wthid[i], NULL);

    pthread_mutex_destroy(&rw_mutex);
    pthread_mutex_destroy(&r_mutex);
    pthread_mutex_destroy(&r_avail);
    pthread_mutex_destroy(&w_mutex);
    exit(0);
}
```

Compile and Run

Compile *"writer_prefer.c"* with GCC. When you run the *"writer_prefer"*, you should see there is an output txt file named *"writer_prefer.txt"*.



The part of writer_prefer.txt file -- (1)



(writers never overlap)

The part of writer_prefer.txt file -- (2)

(writer precedes the Readers)

If you want to see the full text, please take a look inside the *"writer_prefer.txt"*

How does it work? - The Fair Readers Writers

1. **The Mutex "fcfs"**
   Every Reader and Writers should get this mutex that works similarly to the FCFS queue. After a reader or writer get this lock, the process of getting *"r_mutex"* or *"rw_mutex"* is quite similar to the Reader preference. As we agree to allow readers can overlap each other, only the first and last reader lock or unlock the *"rw_mutex"*.
   This mutex may works as a queue since there is no priority between readers and writers. All they need to do is trying to get involved in the *"fcfs"* queue as soon as possible. Every reader and writer will compete to get this mutex lock, and this guarantees that there is no starvation.

2. **The Mutex "r_mutex"**
   Same as the previous one. When readers want to do their service, they need to count up or down the *r_cnt*. This is still a critical problem since *r_cnt* should be calculated one by one.

3. **The Mutex "rw_mutex"**
   The shared mutex when readers or writers run themselves. As the runner can overlap with other runners, only the first runner locks this mutex, and the last mutex unlocks it. However, writers cannot overlap not only with the readers but also other writers. The *"rw_mutex"* will be used whenever the writer wants to run itself.

Codes - The Fair Readers Writers

```
/*
 * Copyright 2020, 2021. Heekuck Oh, all rights reserved
 * 이 프로그램은 한양대학교 ERICA 소프트웨어학부 재학생을 위한 교육용으로 제작되었습니다.
 */
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#include <pthread.h>
#include <unistd.h>
#include <fcntl.h>

#define N 8192
#define L1 75
#define L2 70
#define L3 70
#define RNUM 10
#define WNUM 3

/*
 ...
 ...
 face picture with a number of chars...
 ...
 */



/*
 * alive 값이 1이면 각 스레드는 무한 루프를 돌며 반복해서 일을 하고,
 * alive 값이 0이 되면 무한 루프를 빠져나와 스레드를 자연스럽게 종료한다.
 */
int alive = 1;
pthread_mutex_t rw_mutex;
pthread_mutex_t r_mutex;
pthread_mutex_t fcfs;
int r_cnt = 0;

/*
 * Reader 스레드는 같은 문자를 N번 출력한다. 예를 들면 <AAA...AA> 이런 식이다.
 * 출력할 문자는 인자를 통해 0이면 A, 1이면 B, ..., 등으로 출력하며, 시작과 끝을 <...>로 나타낸다.
 * 단일 reader라면 <AAA...AA>처럼 같은 문자만 출력하겠지만, critical section에서 reader의
 * 중복을 허용하기 때문에 reader가 많아지면 출력이 어지럽게 섞여서 나오는 것이 정상이다.
 */
void *reader(void *arg)
```

```
{
    int id, i;

    /*
    * 들어온 인자를 통해 출력할 문자의 종류를 정한다.
    */
    id = *(int *)arg;
    /*
    * 스레드가 살아 있는 동안 같은 문자열 시퀀스 <XXX...XX>를 반복해서 출력한다.
    */
    while (alive) {
        pthread_mutex_lock(&fcfs);  // reader goes to fcfs q and waits
            pthread_mutex_lock(&r_mutex); // r_cnt cannot be accessed at the same
                if(++r_cnt == 1) pthread_mutex_lock(&rw_mutex); // first reader get rw_mutex for others
            pthread_mutex_unlock(&r_mutex);
        pthread_mutex_unlock(&fcfs);

        /*
        * Begin Critical Section
        */
        printf("<");
        for (i = 0; i < N; ++i)
        printf("%c", 'A'+id);
        printf(">");
        /*
        * End Critical Section
        */

        pthread_mutex_lock(&r_mutex);
        if(--r_cnt == 0) pthread_mutex_unlock(&rw_mutex);    // last reader unlock the rw_mutex
                                                             // so that others can use it
        pthread_mutex_unlock(&r_mutex);
    }
    pthread_exit(0);
}

/*
* Writer 스레드는 어떤 사람의 얼굴 이미지를 출력한다.
* 이미지는 세 가지 종류가 있으며 인자를 통해 식별한다.
* Writer가 critical section에 있으면 다른 writer는 물론이고 어떠한 reader도 들어올 수 없다.
* 만일 이것을 어기고 다른 writer나 reader가 들어왔다면 얼굴 이미지가 깨져서 쉽게 감지된다.
*/
void *writer(void *arg)
{
    int id, i;
    struct timespec req, rem;

    /*
    * 들어온 인자를 통해 얼굴 이미지의 종류를 정한다.
```

```
    */
    id = *(int *)arg;
    /*
    * 이미지 출력을 천천히 하기 위해 한 줄 출력할 때마다 쉬는 시간을 1 나노초로 설정한다.
    */
    req.tv_sec = 0;
    req.tv_nsec = 1L;
    /*
    * 스레드가 살아 있는 동안 같은 이미지를 반복해서 출력한다.
    */
    while (alive) {
        pthread_mutex_lock(&fcfs);   // writer goes to fcfs q and waits
            pthread_mutex_lock(&rw_mutex);   // when writer's turn in fcfs, get rw_mutex
        pthread_mutex_unlock(&fcfs);   // complete pushing to q

        /*
        * Begin Critical Section
        */
        printf("\n");
        switch (id) {
        case 0:
            for (i = 0; i < L1; ++i) {
                printf("%s\n", t[i]);
                nanosleep(&req, &rem);
            }
            break;
        case 1:
            for (i = 0; i < L2; ++i) {
                printf("%s\n", d[i]);
                nanosleep(&req, &rem);
            }
            break;
        case 2:
            for (i = 0; i < L3; ++i) {
                printf("%s\n", e[i]);
                nanosleep(&req, &rem);
            }
            break;
        default:
            ;
        }
        /*
        * End Critical Section
        */

        pthread_mutex_unlock(&rw_mutex);   // release rw_mutex so that others can use it
    }
    pthread_exit(0);
}
```

```
/*
 * 메인 함수는 RNUM 개의 reader 스레드를 생성하고, WNUM 개의 writer 스레드를 생성한다.
 * 생성된 스레드가 일을 할 동안 0.2초 동안 기다렸다가 alive의 값을 0으로 바꿔서 모든 스레드가
 * 무한 루프를 빠져나올 수 있게 만든 후, 스레드가 자연스럽게 종료할 때까지 기다리고 메인을 종료한다.
 */
int main(void)
{
    int i;
    int rarg[RNUM], warg[WNUM];
    pthread_t rthid[RNUM];
    pthread_t wthid[WNUM];
    struct timespec req, rem;

    // stdout is now the txt file
    int output_fd = open("fair_reader_writer.txt", O_CREAT|O_TRUNC|O_RDWR, 0666);
    dup2(output_fd, STDOUT_FILENO);

    pthread_mutex_init(&rw_mutex, NULL);
    pthread_mutex_init(&r_mutex, NULL);
    pthread_mutex_init(&fcfs, NULL);

    /*
     * Create RNUM reader threads
     */
    for (i = 0; i < RNUM; ++i) {
        rarg[i] = i;
        if (pthread_create(rthid+i, NULL, reader, rarg+i) != 0) {
            fprintf(stderr, "pthread_create error\n");
            exit(-1);
        }
    }
    /*
     * Create WNUM writer threads
     */
    for (i = 0; i < WNUM; ++i) {
        warg[i] = i;
        if (pthread_create(wthid+i, NULL, writer, warg+i) != 0) {
            fprintf(stderr, "pthread_create error\n");
            exit(-1);
        }
    }
    /*
     * Wait for 0.2 second while the threads are working
     */
    req.tv_sec = 0;
    req.tv_nsec = 200000000L;
    nanosleep(&req, &rem);
    /*
```

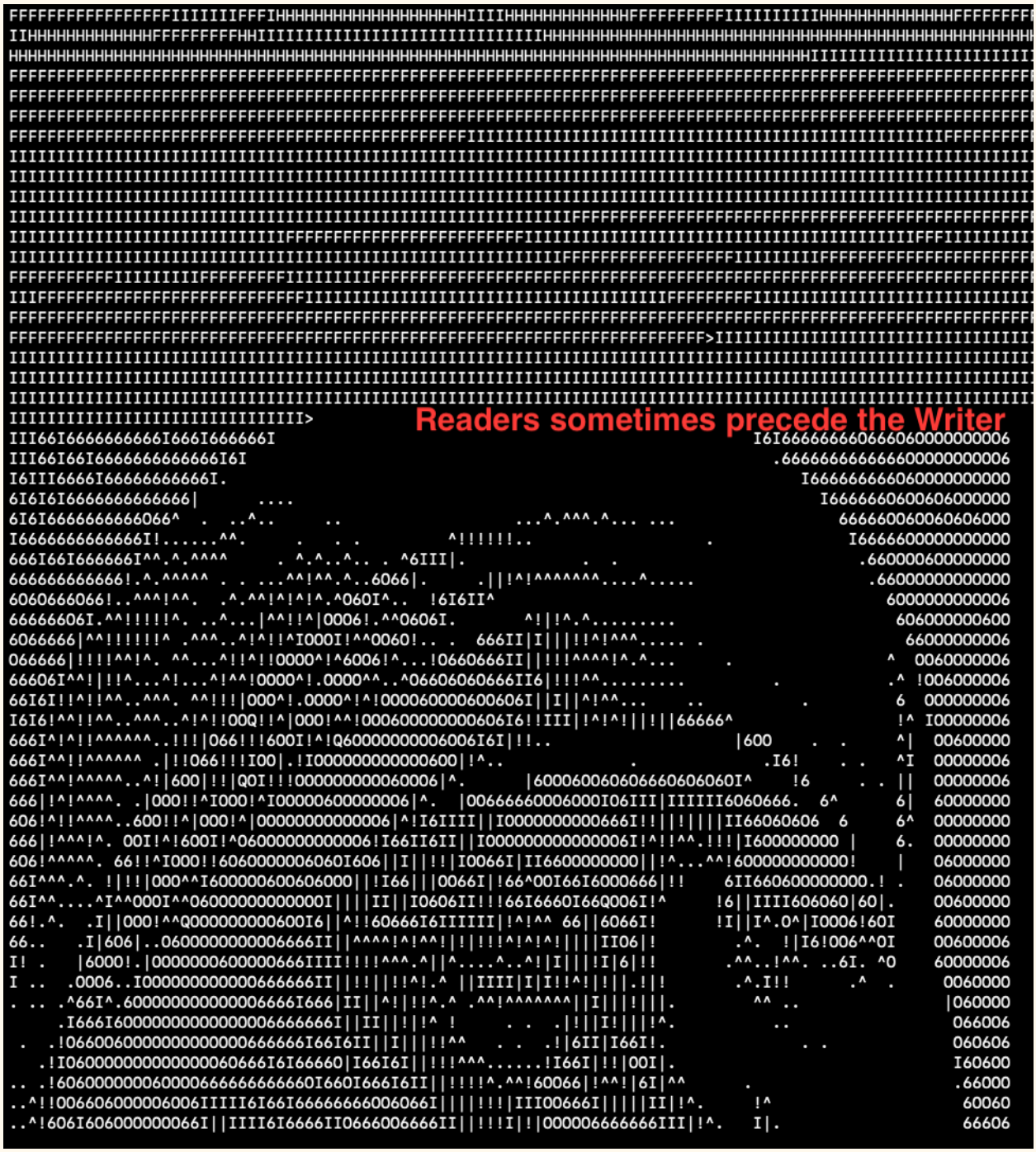
```
     * Now terminate all threads and leave
     */
    alive = 0;
    for (i = 0; i < RNUM; ++i)
        pthread_join(rthid[i], NULL);
    for (i = 0; i < WNUM; ++i)
        pthread_join(wthid[i], NULL);

    pthread_mutex_destroy(&rw_mutex);
    pthread_mutex_destroy(&r_mutex);
    pthread_mutex_destroy(&fcfs);

    exit(0);
}
```

Compile and Run

Compile *"fair_reader_writer.c"* with GCC. When you run the *"fair_read_writer"*, you should see there is an output txt file named *"fair_reader_writer.txt"*.

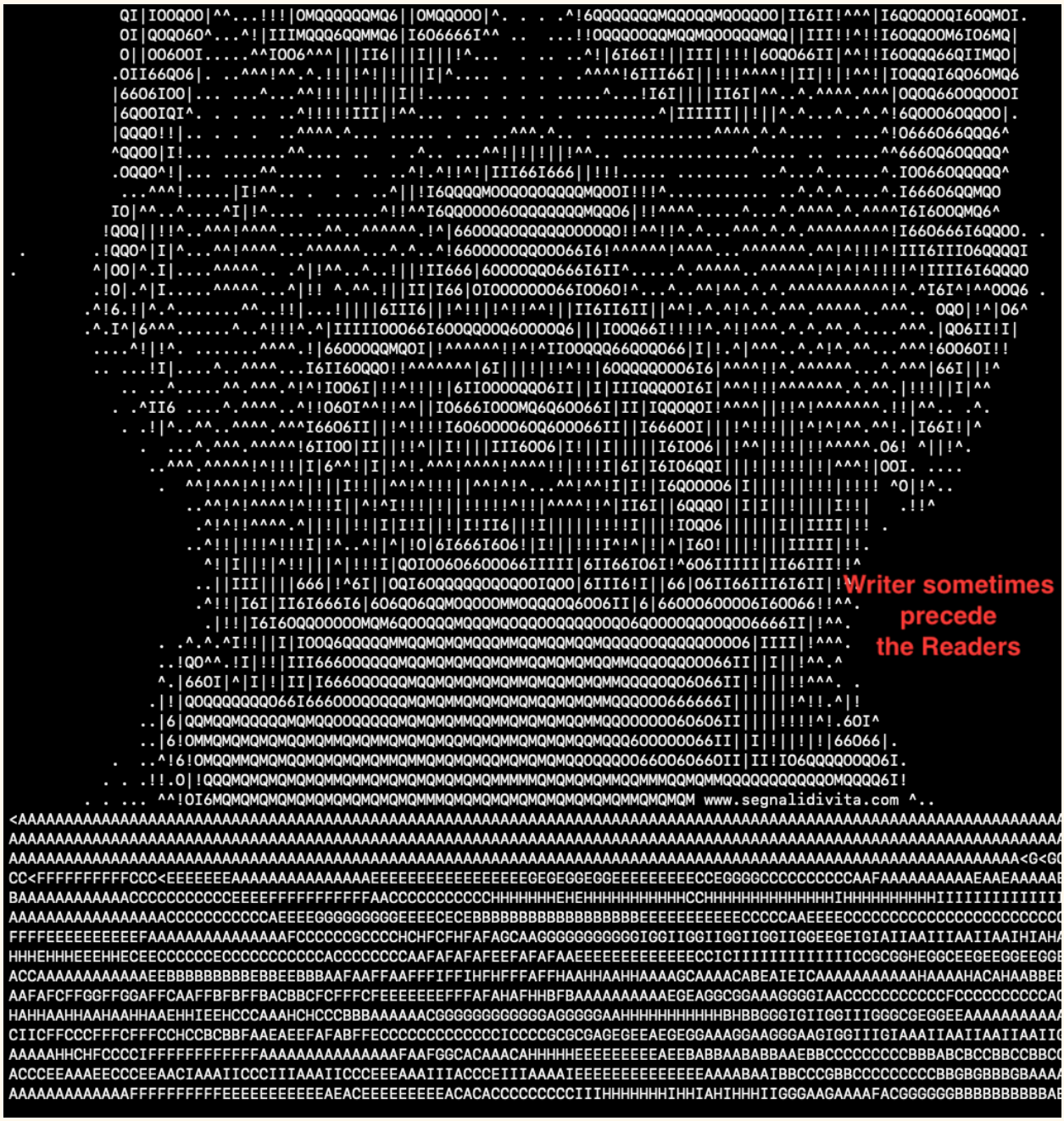
```
(base) jihonggeun:~/Library/Mobile Documents/com~apple~CloudDocs/Study/HYU/2021/Operating Syst
 (main)  ls
fair_reader_writer.c writer_prefer        writer_prefer.c      writer_prefer.txt
(base) jihonggeun:~/Library/Mobile Documents/com~apple~CloudDocs/Study/HYU/2021/Operating Syst
 (main)  gcc -o fair_reader_writer fair_reader_writer.c
(base) jihonggeun:~/Library/Mobile Documents/com~apple~CloudDocs/Study/HYU/2021/Operating Syst
 (main)  ./fair_reader_writer
(base) jihonggeun:~/Library/Mobile Documents/com~apple~CloudDocs/Study/HYU/2021/Operating Syst
 (main)  lslaf
total 3776
drwxr-xr-x@ 8 jihonggeun  staff      256 May 14 14:52 ./
drwxr-xr-x@ 9 jihonggeun  staff      288 May 14 14:52 ../
-rwxr-xr-x  1 jihonggeun  staff    66904 May 14 14:57 fair_reader_writer*
-rw-r--r--  1 jihonggeun  staff   103535 May 14 09:47 fair_reader_writer.c
-rw-r--r--  1 jihonggeun  staff   547768 May 14 14:57 fair_reader_writer.txt
-rwxr-xr-x  1 jihonggeun  staff    67000 May 14 14:48 writer_prefer*
-rw-r--r--  1 jihonggeun  staff   103742 May 14 09:46 writer_prefer.c
-rw-r--r--  1 jihonggeun  staff  1029049 May 14 14:48 writer_prefer.txt
(base) jihonggeun:~/Library/Mobile Documents/com~apple~CloudDocs/Study/HYU/2021/Operating Syst
 (main)
```

The part of fair_reader_writer.txt file -- (1)



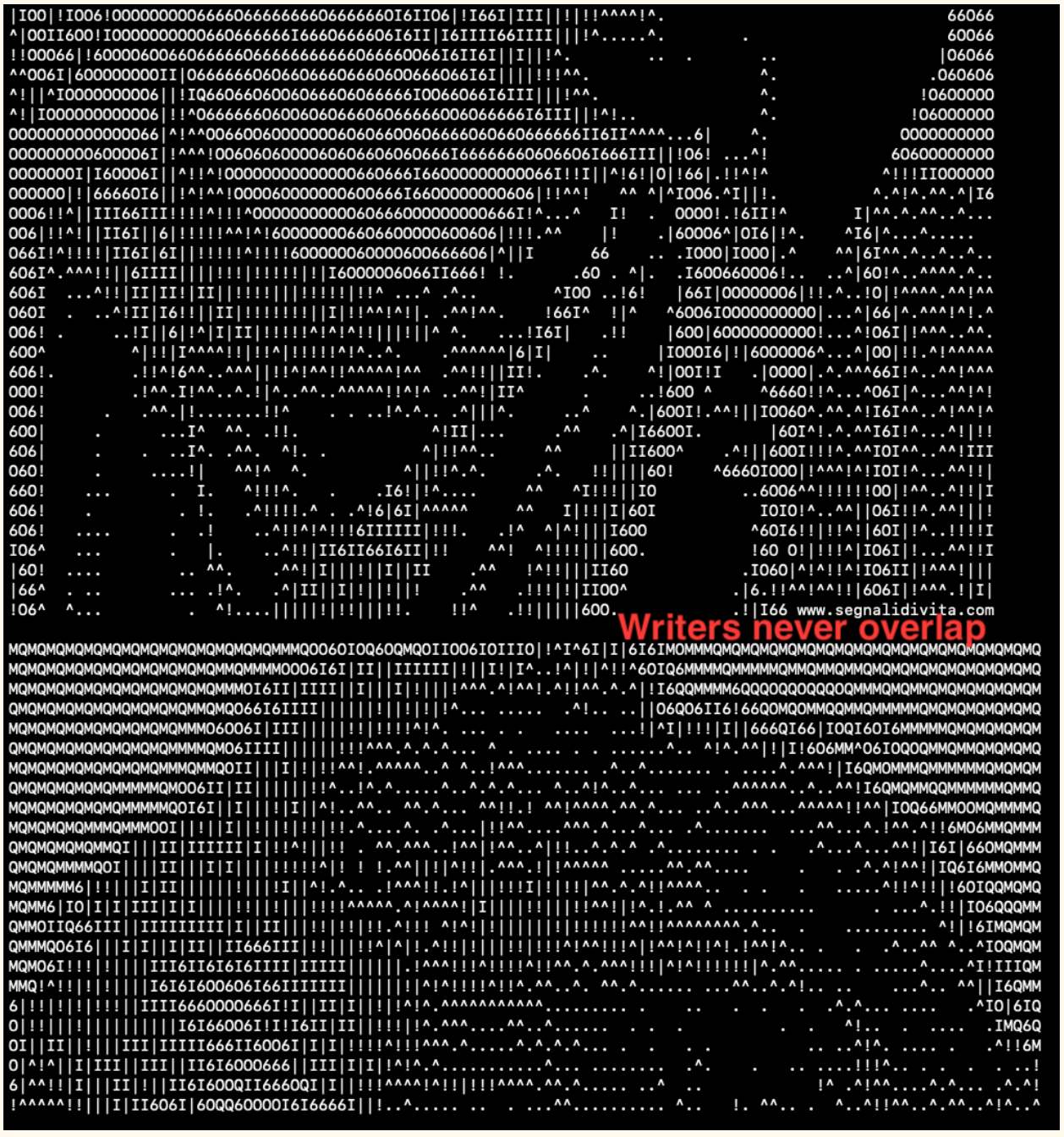
(readers sometimes precede the writer)

The part of fair_reader_writer.txt file -- (2)



(writer sometimes precede the readers)

The part of fair_reader_writer.txt file -- (3)



(writers never overlap)

If you want to see the full text, please take a look inside the *"fair_reader_writer.txt"*