进程与线程并发

小组成员与分工：

- 陆昊宇：实现 C++ 版本代码、完成可视化代码；
- 董文杰：实现 Python 版本代码、完成报告撰写。

实验环境

操作系统：Windows 11

g++ 版本：13.1.0

C++ 标准：c++20

python 版本：3.11

实验目的

实现多线程统计单词数量

统计规则：凡一个非数字或字母跟在数字或字母后面, 这个数字或字母被视为单词结尾.

本实验将基于上述统计规则，在 C++ 和 Python 双语的情况下使用两种方式完成上述任务。并在小样本上可视化, 大样本上测试.

实验准备

小样本文件

1. 包含 26 个字母: a b c ... x y z
2. 包含两组 26 个字母: a b c ... x y z a b c ... x y z
3. 包含 26 个字母重复 2 次: aa bb cc ... xx yy zz
4. 包含 26 个字母重复 3 次: aaa bbb ccc ... xxx yyy zzz

大样本文件

使用 `numpy` 中的文件作为样本测试.

实验方法

方法一

两个线程共享一个全局变量 `total_words`

当一个线程扫描到一个单词时, 就更新 `total_words` 变量

对 `total_words` 变量的更新必须互斥访问, 因此, 需要使用 `semaphore` 信号量

最后主程序输出 `total_words` 即可

方法二

两个变量不共享变量, 各自独立统计各自文件的单词数.

当线程结束后, 将统计的单词个数返回给主线程.

主程序等两个线程都结束后, 将两个返回值相加, 得到单词总数.

可视化

线程向 `ans.out` 文件中输出每个单词结束时的时间.

可视化程序从 `ans.out` 中获取时间信息.

根据获取到的时间信息动态还原单词统计的过程.

实验步骤

1. 完成方法一的程序, 并在控制台上测试小样本.

   例如使用命令: `g++ solution1.cpp -o solution.exe && solution.exe word1.txt word2.txt`
2. 完成方法二的程序, 并在控制台上测试小样本.

   例如使用命令: `g++ solution2.cpp -o solution.exe && solution.exe word1.txt word2.txt`
3. 完成可视化程序, 并测试小样本.

   例如使用命令: `g++ solution1.cpp -o solution.exe && solution.exe word1.txt word2.txt && python main.py`
4. 测试大样本.
5. 扩展代码, 根据输入的文件数量创建相应数量的线程.
6. 测试小样本并可视化, 测试大样本.

实验结果

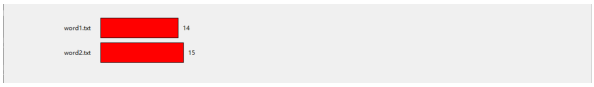
小样本终端测试

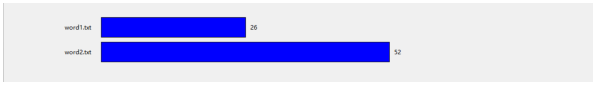
```
F:\OS_Simulate\Experiment7>g++ solution1.cpp -o solution.exe && solution.exe word1.txt word2.txt
Total words: 78

F:\OS_Simulate\Experiment7>g++ solution2.cpp -o solution.exe && solution.exe word1.txt word2.txt
Total words: 78
```

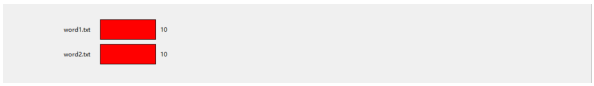
小样本可视化分析

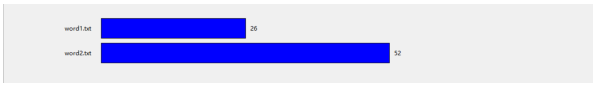
方法一





方法二





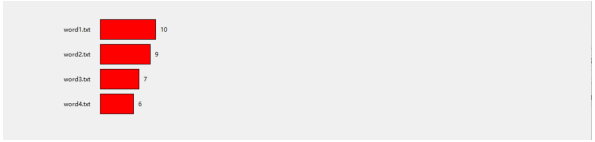
大样本分析测试

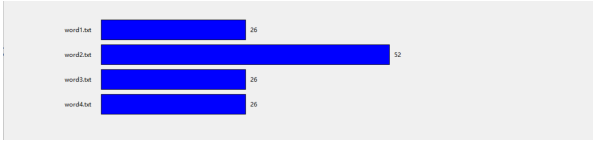
```
F:\OS_Simulate\Experiment7>g++ solution1.cpp -o solution.exe && solution.exe word11.txt word12.txt
Total words: 4166

F:\OS_Simulate\Experiment7>g++ solution2.cpp -o solution.exe && solution.exe word11.txt word12.txt
Total words: 4166
```

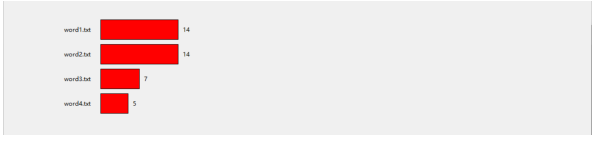
代码扩展测试

方法一





方法二



实验分析

1. 由于 C++ 读写速度过快, 需要在每次 `getchar` 后停顿一段固定时间展示差异性. (此处是为了可视化效果, 在大样本测试中不需要)
2. 由于多个线程可能会同时结束, 向 `ans.out` 中写入信息时会错乱, 需要一个信号量互斥写入.
3. 从 `ans.out` 的信息中可以看出, 两个线程确实在并发执行. 在资源充足的情况下, 这样做可以很大程度的降低计算所需的时间.

ans.out

```
File$$word1.txt$$: 131 269 409 548 688 842 982 1121 1261 1398 1539 1677 1814 1955 2093 2247 2385 2522 2660 2799 2938 3093 3232 3370
3509 3649
File$$word2.txt$$: 131 269 409 549 688 842 982 1121 1261 1398 1539 1677 1814 1955 2093 2247 2385 2522 2660 2799 2938 3093 3232 3370
3509 3649 3787 3925 4064 4218 4372 4510 4648 4787 4926 5065 5204 5358 5497 5636 5774 5914 6052 6189 6328 6481 6619 6758 6897 7036
7177 7316
```

4. 由于第二种方法不需要互斥访问 `total_words`, 时间效率更高.

附录

实验代码已经上传到 github 仓库：https://github.com/Explorer-Dong/OS_Simulate/tree/main/Experiment7

solution1.cpp

```cpp
#include <bits/stdc++.h>
#include <pthread.h>
#include <ctype.h>
#include <semaphore.h>
using i64 = unsigned long long int;

std::ofstream fout("ans.out");
sem_t mutex_write;

auto get_current_time()
{
    auto now = std::chrono::system_clock::now();
    auto timestamp = std::chrono::duration_cast<std::chrono::milliseconds>
(now.time_since_epoch()).count();
    return timestamp;
};

auto start_time = get_current_time();
```

```
sem_t mutex;
int total_words = 0;
void* count_words(void* arg)
{
    std::vector<i64> time_vec;
    char* filename = (char*)arg;
    FILE *fp;
    int c, prevc = '\0';
    if ((fp = fopen(filename, "r")) != NULL)
    {
        while ((c = getc(fp)) != EOF)
        {
            if (!isalnum(c) && isalnum(prevc))
            {
                sem_wait(&mutex);
                auto cur = get_current_time();
                time_vec.push_back(cur - start_time);
                total_words++;
                std::this_thread::sleep_for(std::chrono::milliseconds(100));
                sem_post(&mutex);
            }
            else std::this_thread::sleep_for(std::chrono::milliseconds(100));
            prevc = c;
        }
        if (isalnum(prevc))
        {
            sem_wait(&mutex);
            auto cur = get_current_time();
            time_vec.push_back(cur - start_time);
            total_words++;
            sem_post(&mutex);
        }
        fclose(fp);
    }
    else
        perror(filename);

    sem_wait(&mutex_write);

    fout << "File$$" << filename << "$$: ";
    for (auto time :time_vec) fout << time << " ";
    fout << "\n";

    sem_post(&mutex_write);

    return nullptr;
}
```

```
int main(int ac, char *av[])
{
    if (ac < 3)
    {
        printf("Usage:%s file1 file2\n", av[0]);
        return 1;
    }

    sem_init(&mutex, 0, 1);
    sem_init(&mutex_write, 0, 1);

    std::vector<pthread_t> t(ac);
    for (int i = 1; i < ac; i++)
    {
        pthread_create(&t[i], nullptr, count_words, av[i]);
    }

    for (int i = 1; i < ac; i++)
    {
        pthread_join(t[i], nullptr);
    }

    printf("Total words: %d\n", total_words);

    sem_destroy(&mutex_write);
    sem_destroy(&mutex);

    return 0;
}
```

solution2.cpp

```
#include <bits/stdc++.h>
#include <pthread.h>
#include <ctype.h>
#include <semaphore.h>
using i64 = unsigned long long int;

std::ofstream fout("ans.out");
sem_t mutex_write;

struct buf
{
    char* filename;
```

```
    int wc_count;
};


auto get_current_time()
{
    auto now = std::chrono::system_clock::now();
    auto timestamp = std::chrono::duration_cast<std::chrono::milliseconds>
(now.time_since_epoch()).count();
    return timestamp;
};

auto start_time = get_current_time();

void* count_words(void* arg)
{
    std::vector<i64> time_vec;
    buf* ptr = (buf*)arg;
    char* filename = ptr->filename;
    FILE *fp;
    int c, prevc = '\0';
    if ((fp = fopen(filename, "r")) != NULL)
    {
        while ((c = getc(fp)) != EOF)
        {
            if (!isalnum(c) && isalnum(prevc))
            {
                auto cur = get_current_time();
                time_vec.push_back(cur - start_time);
                ptr->wc_count++;
            }
            else std::this_thread::sleep_for(std::chrono::milliseconds(100));

            prevc = c;
            std::this_thread::sleep_for(std::chrono::milliseconds(1));
        }
        if (isalnum(prevc))
        {
            auto cur = get_current_time();
            time_vec.push_back(cur - start_time);
            ptr->wc_count++;
        }
        fclose(fp);
    }
    else
        perror(filename);
```

```
    sem_wait(&mutex_write);

    fout << "File$$" << filename << "$$: ";
    for (auto time :time_vec) fout << time << " ";
    fout << "\n";

    sem_post(&mutex_write);

    pthread_exit((void*)&ptr->wc_count);
    return nullptr;
}

int main(int ac, char *av[])
{
    if (ac < 3)
    {
        printf("Usage:%s file1 file2\n", av[0]);
        return 1;
    }
    sem_init(&mutex_write, 0, 1);

    std::vector<buf> args(1);
    for (int i = 1; i < ac; i++)
    {
        args.push_back({av[i], 0});
    }

    std::vector<pthread_t> t(ac);
    for (int i = 1; i < ac; i++)
    {
        if (pthread_create(&t[i], nullptr, count_words, &args[i]) != 0)
        {
            perror("pthread_create");
            return 1;
        }
    }

    std::vector<void*> result(ac);

    for (int i = 1; i < ac; i++)
    {
        pthread_join(t[i], &result[i]);
    }

    int total_words = 0;
    for (int i = 1; i < ac; i++)
    {
```

```
        total_words += *((int*)result[i]);
    }
    printf("Total words: %d\n", total_words);

    sem_destroy(&mutex_write);
    return 0;
}
```

main.py

```
r"""
This is the main window of the experiment.
To run the experiment, you can use the following command in the terminal:
g++ .\solution1.cpp -o .\solution.exe && .\solution.exe .\word1.txt
.\word2.txt && python .\main.py
"""

import tkinter as tk


class Process:
    def __init__(self, data_arr):
        self.name = data_arr[0]
        self.time_sequence = data_arr[1:]
        self.name = self.name.split("$$")[1]
        self.time_sequence = list(map(int, self.time_sequence))
        self.idx = 0  # cnt = idx
        self.max_idx = len(self.time_sequence)

    @property
    def finished(self):
        return self.idx >= self.max_idx

    def run(self, time):
        while not self.finished and self.time_sequence[self.idx] <= time:
            self.idx += 1
        return self.name, self.idx, self.finished


class Counter:
    def __init__(self, data, step):
        self.processes = [Process(d.split()) for d in data]
        self.processes.sort(key=lambda p: p.name)
        self.step = step
        self.now = 0
```

```
    @property
    def finished(self):
        return all(p.finished for p in self.processes)

    def next_moment(self):
        if self.finished:
            return None
        self.now += self.step
        cnt = [p.run(self.now) for p in self.processes]
        return cnt

    @property
    def max_size(self):
        return max(p.max_idx for p in self.processes)


data = open('ans.out', 'r').readlines()
# print(data)
root = tk.Tk()
root.title("柱状图")
canvas_width = 1000
canvas_height = len(data) * 50 + 200  # 每行占50像素高度
root.geometry(f"1200x600")
canvas = tk.Canvas(root, width=canvas_width, height=canvas_height)
canvas.pack()

x_offset = 100  # 起始X偏移量
y_offset = 100  # 起始Y偏移量
bar_height = 40  # 每个柱状图的高度


def display(counts, rate):
    canvas.delete("all")
    for i, (label, length, color_flag) in enumerate(counts):
        # 计算柱状图的长度（按比例缩放至画布宽度）
        bar_length = (canvas_width - 300) * rate * length
        color = "blue" if color_flag else "red"

        # 绘制标签
        canvas.create_text(x_offset - 20, y_offset + i * 50 + bar_height / 2,
text=label, anchor="e")

        # 绘制柱状图
        canvas.create_rectangle(x_offset, y_offset + i * 50, x_offset +
bar_length, y_offset + i * 50 + bar_height,
                                fill=color)
```

```
        # 在柱状图右侧显示长度
        canvas.create_text(x_offset + bar_length + 10, y_offset + i * 50 +
bar_height / 2, text=str(length), anchor="w")


def display_animation(data):
    counter = Counter(data, 100)
    rate = 1 / (counter.max_size + 10)  # 缩放比例
    delay = 100  # 刷新时间（毫秒）
    while not counter.finished:
        counts = counter.next_moment()
        canvas.after(delay, display, counts, rate)
        delay += 100


button = tk.Button(root, text="开始动画", command=lambda:
display_animation(data))
button.pack()
display_animation(data)
root.mainloop()
```

solution1.py

```
import threading
import time, sys

r"""
cd Experiment7
python solution1.py word1.txt word2.txt && python main.py
"""

total_words = 0
mutex = threading.Semaphore(1)
write_mutex = threading.Semaphore(1)
print_step = True

def count_words_in_file(file_path: str) -> None:
    now_words = 0
    start_time = time.time()
    time_step = []

    def count() -> None:
        nonlocal now_words
        mutex.acquire()
        now_words += 1
```

```
            del_t = int((time.time() - start_time) * 1000)
            time_step.append(del_t)
            if print_step:
                print(f"{threading.current_thread().name} update {del_t}")
            mutex.release()

        with open(file_path, 'r') as file:
            last = ' '
            while last:
                char = file.read(1)

                time.sleep(0.01 if print_step else 0)
                if not char:
                    if last.isalnum():
                        count()
                    break

                if not char.isalnum() and last.isalnum():
                    count()

                last = char

            # 互斥写入文件
            write_mutex.acquire()
            global total_words
            total_words += now_words
            file_name = file_path.split('/')[-1]
            with open('./ans.out', 'a') as out_file:
                out_file.write("File$$" + file_name + "$$: ")
                for t in time_step:
                    # print(t)
                    out_file.write(str(t) + ' ')
                out_file.write('\n')
                print(f"write {file_name} down")
            write_mutex.release()

    if __name__ == '__main__':
        open('./ans.out', 'w')
        file1 = sys.argv[1]
        file2 = sys.argv[2]

        thread1 = threading.Thread(target=count_words_in_file, args=(file1, ),
    name='t1')
        thread2 = threading.Thread(target=count_words_in_file, args=(file2, ),
    name='t2')

        thread1.start()
```

```
    thread2.start()

    thread1.join()
    thread2.join()

    print("Total words:", total_words)
```

solution2.py

```
import threading
import time, sys

r"""
python solution2.py word1.txt word2.txt && python main.py
"""

write_mutex = threading.Semaphore(1)
print_step = True

def count_words(file_path, cnt: list[int], no: int) -> None:
    start_time = time.time()
    time_step = []

    with open(file_path, 'r') as f:
        last = ' '
        while last:
            char = f.read(1)
            time.sleep(0.01 if print_step else 0)

            if not char.isalnum() and last.isalnum():
                cnt[no] += 1
                del_t = int((time.time() - start_time) * 1000)
                time_step.append(del_t)
                if print_step:
                    print(f"{threading.current_thread().name} update {del_t}")

            last = char

        # 互斥写入文件
        write_mutex.acquire()
        file_name = file_path.split('/')[-1]
        with open('./ans.out', 'a') as out_file:
            out_file.write("File$$" + file_name + "$$: ")
            for t in time_step:
                # print(t)
```

```
                out_file.write(str(t) + ' ')
            out_file.write('\n')
            print(f"write {file_name} down")
        write_mutex.release()

if __name__ == '__main__':
    open('./ans.out', 'w')
    file1 = sys.argv[1]
    file2 = sys.argv[2]
    count = [0, 0]
    thread1 = threading.Thread(target=count_words, args=(file1, count, 0),
name='t1')
    thread2 = threading.Thread(target=count_words, args=(file2, count, 1),
name='t2')

    thread1.start()
    thread2.start()

    thread1.join()
    thread2.join()

    print("Total words", sum(count))
```