# 北京郵電大學

# 进程管理实验报告



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# 进程管理实验报告

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# 1 任务分析

在并发程序设计中,进程间的同步与协调是一个关键性问题,特别是在多进程或多线程共享资源的场景下,若没有合适的同步机制,系统将面临数据不一致、竞争条件、死锁等问题。

### 1.1 进程同步

**进程同步**是指在多个进程(或线程)并发执行时,确保它们能够按预定的方式协调执行,从而避免竞争条件、死锁等问题。通常在并发程序中,多个进程需要访问共享资源,因此必须控制对这些资源的访问,确保不同进程之间的行为不会相互干扰。

#### 同步的目的包括:

- 避免竞争条件: 当多个进程同时访问和修改共享资源时,可能会出现不一致的情况。进程同步确保只有一个进程能够在特定时间访问共享资源。
- 保证顺序执行: 在某些情况下, 进程的执行顺序必须是有序的, 以满足某些逻辑或业务规则。
- 避免死锁与饥饿: 确保系统资源不会导致进程无限期地等待。

#### 同步机制通常通过以下方式实现:

- 互斥锁 (Mutex): 确保同一时刻只有一个进程能够访问共享资源。
- 信号量 (Semaphore): 控制多个进程对共享资源的访问,可以用于计数或者限制并发访问的数量。
- 条件变量 (Condition Variables): 当进程需要等待某些条件满足时,能够进行有效的等待和通知。

2 实验环境 3

#### 1.2 读者写者问题

读者写者问题是一类经典的同步问题,描述了在并发访问共享数据时,读者(读操作)和写者(写操作)之间的冲突问题。问题的核心在于如何协调多个进程在访问共享资源时,确保读取和写入操作之间不会产生冲突。

- 读者可以同时访问共享资源(多个读者之间不存在冲突);
- 写者在写入时必须独占资源,禁止任何其他读者或写者访问;
- 需要在保证多个读者能够并发读取的同时,又能保证写者在写入时能够独占资源。

#### 1.3 读者优先与写者优先

读者优先和写者优先是读者写者问题的两种调度策略,它们决定了如何处理多个读者和写者的请求。

在读者优先策略下,如果有多个读者和一个写者请求资源,系统优先满足读者的请求,即使有写者请求,若当前没有其他写者,读者仍然可以继续读取。这种策略提高了读操作的并发性。如果读操作远多于写操作,读者优先策略能有效提升系统吞吐量。适用于读多写少的场景,避免写操作的频繁阻塞。但是可能导致写者饥饿。因为读者在某些情况下可以无限制地访问共享资源,导致写者的请求长期无法得到满足。

写者优先策略下,系统尽可能优先满足写者的请求。即使有读者正在访问共享资源,一旦写者请求到来,读者也必须等待写者完成写操作。从而避免了写者的饥饿问题,保证写操作能够及时执行。在写操作较为重要或频繁的场景下,能够保证系统的一致性和正确性。类似的,缺点是可能导致读者的饥饿问题。如果写者频繁获得资源,读者可能长时间无法读取数据。

# 2 实验环境

• 操作系统: macOS Sequoia 15.2 (24C101)

• 编程语言: c++23

• 编译器: clang 19.1.6

• 构建工具: xmake v2.9.7+20241219

• 文档构建工具: doxygen 1.12.0

# 3 设计思路

### 3.1 读者优先

该策略要求多个读者可以并发访问共享资源,而写者在读者完成所有读取操作之前无法进行写入操作。我们通过使用互斥锁和计数器等工具来实现这种同步机制,保证了多个读者和写者之间的有序执行。

#### 3.1.1 资源访问控制的分离

为了正确实现读者优先策略,我们将资源访问控制分为两个互斥锁:

- 读者计数控制 (mtx): 用来追踪当前正在读取的读者数量。通过读者计数来决定是否需要阻 塞写者。
- 写者互斥锁(wrt): 用来确保写者在执行写操作时能够独占资源,并阻止任何其他读者或写者同时访问共享资源。

这种分离机制的关键点在于,读者的数量直接决定写者的访问权限。如果有读者正在进行读取操作,第一个进入临界区的读者会锁定写者互斥锁(wrt),从而阻止写者进入;当最后一个读者离开时,会释放写者互斥锁,允许等待中的写者进入。

#### 对于读者:

- 1. 读者首先通过 mtx 锁来更新 read\_count (当前正在读取的读者数量)。
- 2. 如果这是第一个读者,它会锁定 wrt,阻止写者进入。
- 3. 读者完成读取后,减少 read\_count, 如果这是最后一个读者,则释放 wrt,允许写者进行写操作。

#### 对于写者:

- 1. 写者需要获取 wrt 锁,确保独占资源。
- 2. 写者完成写入操作后释放 wrt, 允许其他读者和写者讲行操作。

#### Algorithm 1: Reader 线程伪代码

关键部分(读取)

输出"[时间戳] Reader reader\_id is reading"

等待 100ms

退出部分

锁 mtx

 $read\_count \leftarrow read\_count - 1$ 

if  $read\_count == 0$  then

| 解锁 wrt // 最后一个读者释放写者锁

解锁 mtx

等待 100ms // 模拟读者之间的间隔

#### Algorithm 2: Writer 线程伪代码

Input: writer\_id
while true do

**入口部分** 锁 *wrt* // 写者独占资源

关键部分 (写入)

输出"[时间戳] Writer writer\_id is writing"

等待 150ms 退出部分

解锁 wrt

等待 150ms // 模拟写者之间的间隔

#### 3.1.2 读者进入与退出的同步机制

在实现读者优先策略时,读者进入和退出共享资源的同步非常重要。通过读者计数 read\_count 和锁 wrt,我们可以确保:

- 多个读者并发:只要没有写者正在写,多个读者可以同时读取。
- 写者等待:写者必须等到所有读者都完成操作后,才能获得 wrt 锁进行写操作。
- 进入部分:每当有读者进入时,先通过 mtx 锁定并增加 read\_count,如果这是第一个读者,那么它会进一步锁定 wrt,阻止写者进入资源区域。
- 退出部分: 当一个读者退出时,减少 read\_count,如果这是最后一个读者,它会释放 wrt,从而允许写者讲入。

#### 3.1.3 写者的访问控制

写者需要独占资源,因此它在进入时必须获取 wrt 锁。在写操作完成后,写者会释放该锁。写者的进入和退出通过 wrt 互斥锁来实现,确保在任何时候只有一个写者能够访问共享资源。

#### 3.1.4 读者与写者的调度

当系统有多个读者和写者时,读者会优先于写者执行。写者在所有读者结束操作后才会获得执行机会。这样就能避免由于大量读者的存在导致写者长时间被阻塞。

虽然在读者优先策略下,写者可能需要等待较长时间,但我们避免了写者因为每次读者进入都被 阻塞的情况。写者会按照顺序等待。

#### 3.1.5 线程模拟与调度

通过模拟多个线程(读者与写者)的并发执行来展示读者优先策略的工作原理。每个线程代表一个读者或写者,读者线程通过不断地读取共享资源并报告其状态,写者线程则通过模拟写操作来展示其被阻塞与释放的过程。

使用 std::this\_thread::sleep\_for 来模拟读者和写者的操作时间,从而可以观察到在高并发情况下的同步与调度。每个线程在执行时,都会根据当前的计数和锁的状态,决定是否能够访问共享资源。通过控制这些线程的执行顺序,我们能够实现读者优先的同步策略。

#### 3.2 写者优先

在读者优先策略中,主要的资源访问管理问题是读者和写者之间的互斥性。读者之间可以并发访问资源,但写者必须等到没有读者在访问时才能进行写操作。这个控制相对简单,因为我们只需要确保:如果有读者在读,写者必须等待。

写者优先策略需要管理更复杂的条件,在有读者访问的情况下,写者必须等待,而在有写者等待的情况下,读者需要阻塞。为了确保写者能够优先执行,系统必须保证:写者必须在没有读者的情况下获得资源,即使有读者在读取资源,写者也应该优先等待(避免出现写者饥饿的问题)。这就需要额外的控制来处理写者和读者之间的优先级关系。

#### 3.2.1 资源访问控制的分离

类似于读者优先策略,我们依然使用两个互斥锁来控制对共享资源的访问,通过这些锁和条件变量,我们能够实现以下控制:

- 读者访问: 多个读者可以并发访问资源, 但必须等到没有写者在写入时才能进入。
- 写者访问:写者优先于读者,写者必须等到没有任何读者在读并且没有其他写者正在写时才能进入。

#### 3.2.2 写者优先的调度策略

在写者优先的策略下,写者优先的核心要求是,在有写者等待的情况下,读者必须等待,直到所有写者完成写操作。

- 读者线程在进入临界区时,会检查是否有写者在写。如果有写者在写,读者必须等待。
- 写者线程在进入临界区时,首先会检查是否没有读者在读,并且没有其他写者在写。如果满足这些条件,写者可以进入并锁定资源。

使用条件变量 cond 来控制线程的等待与唤醒:

- 读者会等待条件变量, 直到没有写者在写入。
- 写者会等待条件变量,直到没有读者在读并且没有其他写者在写入。

#### 3.2.3 读者与写者的同步

为了确保写者优先,我们在关键部分使用了互斥锁来保护共享资源,并且确保写者会优先于读者执行,即使在有读者在读取时,只要写者有待处理的任务,它会在所有读者完成操作后被允许执行。只有在没有写者在写的情况下,读者才能继续读取共享资源。

#### 3.2.4 线程间的协调与等待

通过使用 std::condition\_variable 来协调线程的调度。每当一个线程执行完自己的操作后,它会通知其他线程是否可以继续执行:

- 读者退出时,如果是最后一个读者退出,它会通知等待的写者可以开始写入。
- 写者退出时,它会通知等待的读者或其他写者继续执行。

#### Algorithm 3: Reader 线程伪代码

Input: reader\_id while true do

锁 mtx

等待条件: 等待  $write\ count == 0$  // 确保没有写者在等待

 $read\_count \leftarrow read\_count + 1$ 

if read count == 1 then

| 锁 wrt // 第一个读者锁定写者互斥锁

解锁 mtx

关键部分(读取)

输出"[时间戳] Reader reader\_id is reading"

等待 100ms

退出部分

锁 mtx

 $read\ count \leftarrow read\ count - 1$ 

if read count == 0 then

**解锁** *wrt* // 最后一个读者释放写者互斥锁 **通知所有线程** // 唤醒等待的写者 或读者

解锁 mtx

等待 100ms // 模拟读者之间的时间间隔

- 读者线程: 在进入临界区前,必须等待直到没有写者在进行写操作。在读者操作完毕后,若是最后一个读者,它会释放写者的互斥锁并通知其他等待线程。
- 写者线程:写者必须确保在没有读者在读,并且没有其他写者正在写时,才能锁定资源。写 者操作结束后,会释放锁并通知所有等待的线程。

#### Algorithm 4: Writer 线程伪代码

```
Input: writer id
while true do
  锁 mtx
  write\_count \leftarrow write\_count + 1
  等待条件: 等待 read\ count == 0 // 确保没有读者在读 等待条件: 等待
   wrt_locked == false // 确保没有其他写者在写
  wrt\_locked \leftarrow true // 标记写者锁定 锁 wrt // 锁定写者互斥锁
  解锁 mtx
  关键部分(写入)
  输出"[时间戳] Writer writer_id is writing"
  等待 150ms
  退出部分
  解锁 wrt // 解锁写者互斥锁 锁 mtx
  write\_count \leftarrow write\_count - 1
  wrt\_locked \leftarrow false
  通知所有线程 // 唤醒等待的写者或读者 解锁 mtx
  等待 150ms // 模拟写者之间的时间间隔
```

# 4 系统框架及关键代码

#### 4.1 获取当前时间的函数

```
std::string current_time()
   {
        auto now = std::chrono::system clock::now();
3
        auto in time t = std::chrono::system clock::to time t(now);
        auto duration = now.time since epoch();
        auto milliseconds =
           std::chrono::duration cast<std::chrono::milliseconds>(duration) % 1000;
        std::tm buf {};
        localtime_r(&in_time_t, &buf);
10
        std::stringstream ss;
11
        ss << std::put_time(&buf, "%Y-%m-%d %X")
12
           << '.' << std::setw(3) << std::setfill('0') << milliseconds.count();</pre>
13
```

```
return ss.str();

15 }
```

该函数返回当前系统时间的字符串表示,包括年、月、日、时、分、秒和毫秒:

- 使用 std::chrono::system\_clock::now() 获取当前时间点。
- 将时间转换为 time\_t 类型,并通过 localtime\_r 获取本地时间,没有使用传统的 std::l」 ocaltime,确保多线程环境下的安全性。localtime\_r 是 POSIX 标准的线程安全函数,返 回的结果存储在用户提供的 std::tm 结构中。
- 利用 std::put\_time 格式化时间,并用 std::chrono::duration\_cast 获取毫秒部分,最后将其拼接成完整的时间字符串。

### 4.2 ANSI 颜色代码定义

```
#define RESET "\033[0m"

#define GREEN "\033[32m"

#define RED "\033[31m"
```

这部分代码定义了控制台输出的颜色代码。用于在终端中为输出的读者和写者信息着色:

- RESET 用于重置终端的颜色。
- GREEN 用于输出读者信息时使用绿色。
- RED 用于输出写者信息时使用红色。

从而将读者和写者的输出区分开来,方便观察。

# 4.3 读者优先: ReadersPriority 类

该类包含了实现读者优先策略的核心逻辑。它管理读者和写者的同步,以及记录当前有多少个读者在访问共享资源。

#### 4.3.1 数据成员

```
private:
    std::mutex mtx; // read_count

std::mutex wrt; //

int read_count = 0; //

std::mutex cout_mtx; //
```

- mtx: 用于保护 read\_count 变量,确保对读者数量的并发修改是安全的。
- wrt: 用于保护写者的访问,确保同一时刻只有一个写者能够修改资源。
- read\_count: 记录当前正在读取的读者数量。读者数量为零时,允许写者进行写操作。
- cout\_mtx: 用于保护控制台输出的互斥锁,避免多个线程同时输出信息导致输出混乱。

#### 4.3.2 reader 方法

```
void reader(int reader id)
    {
2
        while (true) {
            //
            {
5
                 std::unique_lock<std::mutex> lock(mtx);
6
                read_count++;
                 if (read count == 1) {
                     wrt.lock(); //
                                                     wrt
9
                }
10
            }
11
12
            //
13
            {
14
                 std::lock_guard<std::mutex> lock(cout_mtx);
15
                 std::cout << "[" << current_time() << "] "
16
```

```
<< GREEN << "Reader " << reader_id << " is reading." <<
17
                                 RESET << "\n";</pre>
             }
18
             std::this_thread::sleep_for(std::chrono::milliseconds(100)); //
19
20
             //
21
             {
22
                 std::unique_lock<std::mutex> lock(mtx);
23
                 read_count--;
24
                 if (read_count == 0) {
25
                      wrt.unlock(); //
                                                           wrt
26
                 }
27
             }
28
29
             //
30
             std::this_thread::sleep_for(std::chrono::milliseconds(100));
31
        }
32
    }
33
```

- 入口部分: 当一个读者准备读取时,它会锁定 mtx 互斥锁并增加 read\_count。如果这是第一个读者,它会锁定 wrt,阻止写者进入。
- 关键部分:在这部分,读者执行实际的读取操作,并输出日志,模拟读取的过程。然后使用std::this\_thread::sleep\_for模拟读取过程的延时。
- 退出部分: 当一个读者退出时,它会减少 read\_count。如果这是最后一个读者,释放 wrt 锁,允许写者进入。
- 时间间隔: 模拟读者之间的时间间隔, 使得多次读者的访问能够间隔执行。

#### 4.3.3 writer 方法

```
void writer(int writer_id)
   {
        while (true) {
3
            //
4
            wrt.lock();
            //
            {
                std::lock guard<std::mutex> lock(cout mtx);
9
                std::cout << "[" << current_time() << "] "
10
                           << RED << "Writer " << writer_id << " is writing." <<
11
                               RESET << "\n";
            }
12
            std::this_thread::sleep_for(std::chrono::milliseconds(150)); //
13
14
            //
15
            wrt.unlock();
16
17
            //
18
            std::this_thread::sleep_for(std::chrono::milliseconds(150));
19
        }
20
   }
21
```

- 入口部分:写者首先会获取 wrt 锁,这样可以确保写操作是独占的,即在同一时刻只有一个写者可以执行写入。
- 关键部分: 写者执行写入操作并输出日志,模拟写入过程的延迟。
- 退出部分: 写操作完成后, 写者释放 wrt 锁。

• 时间间隔:模拟多个写者之间的时间间隔。

#### 4.3.4 main 函数

```
int main()
    {
2
        ReadersPriority rw;
3
        std::vector<std::thread> threads;
4
5
        //
6
        for (int i = 1; i <= 5; ++i) {
7
            threads.emplace back(&ReadersPriority::reader, &rw, i);
        }
10
        //
11
        for (int i = 1; i <= 2; ++i) {
12
            threads.emplace_back(&ReadersPriority::writer, &rw, i);
13
        }
14
15
        //
16
        for (auto& th : threads) {
17
            th.join();
        }
19
20
        return 0;
21
22
```

- main 函数创建多个读者和写者线程,并将它们存储在 threads 向量中。
- 创建 5 个读者线程,每个线程会执行 reader 方法,传入不同的 reader id。
- 创建 2 个写者线程,每个线程会执行 writer 方法,传入不同的 writer\_id。

• 线程等待:通过 join 方法等待所有线程结束。在这个例子中,由于线程内的循环是无限的, 所以程序会一直运行。

# 4.4 写者优先: WritersPriority 类

读者可以并发读取共享资源,而写者在有任何读者的情况下必须等待,直到所有读者完成读取任务。

数据成员定义和主函数与读者优先类似,不再赘述。

#### 4.4.1 reader 方法

```
void reader(int reader id)
    {
        while (true) {
3
            //
4
            {
5
                 std::unique_lock<std::mutex> lock(mtx);
                 read_count++;
                 if (read count == 1) {
                     wrt.lock(); //
                                                      wrt
9
                 }
10
            }
11
12
            //
13
            {
14
                 std::lock_guard<std::mutex> lock(cout_mtx);
15
                 std::cout << "[" << current_time() << "] "
                            << GREEN << "Reader " << reader id << " is reading." <<</pre>
17

→ RESET << "\n";
</pre>
            }
18
            std::this_thread::sleep_for(std::chrono::milliseconds(100)); //
19
```

```
20
             //
^{21}
             {
22
                 std::unique lock<std::mutex> lock(mtx);
23
                 read_count--;
24
                 if (read count == 0) {
25
                      wrt.unlock(); //
                                                            wrt
                 }
27
             }
28
29
             //
30
             std::this thread::sleep for(std::chrono::milliseconds(100));
        }
32
33
```

- 入口部分:每个读者线程在进入临界区前,首先使用 mtx 锁保护对 read\_count 的修改。如果当前是第一个进入的读者(read\_count == 1),则锁定 wrt,阻止写者写入。
- 关键部分(读取): 读者在此进行读取操作,并输出当前读者的状态。
- 退出部分:每个读者线程完成读取后,会再次使用 mtx 锁保护,减少 read\_count。如果当前是最后一个离开的读者(read\_count == 0),释放 wrt 锁,允许写者访问资源。

#### 4.4.2 writer 方法

```
std::lock_guard<std::mutex> lock(cout_mtx);
9
                std::cout << "[" << current_time() << "] "
10
                           << RED << "Writer " << writer id << " is writing." <<
11
                              RESET << "\n";
            }
12
            std::this_thread::sleep_for(std::chrono::milliseconds(150)); //
13
14
            //
15
            wrt.unlock();
16
17
            //
18
            std::this_thread::sleep_for(std::chrono::milliseconds(150));
19
        }
20
21
```

- 写者需要独占共享资源。在写者执行写入操作时,其他写者和所有读者都必须等待。
- 写者通过 wrt.lock() 直接锁定 wrt 来实现独占访问,保证写操作的互斥性。

# 5 功能模块图与模块流程图

由 doxygen 自动生成。

6 测试 18

# 5.1 读者优先策略

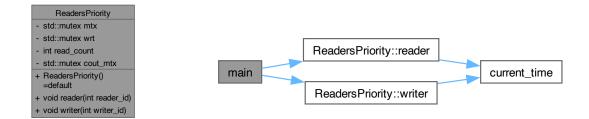


图 1: 读者优先功能模块

图 2: 读者优先模块流程图

图

# 5.2 写者优先策略

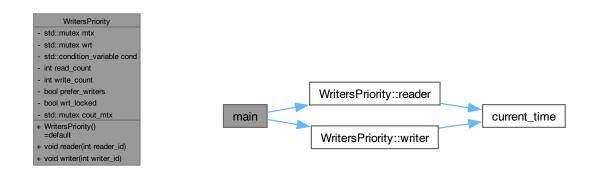


图 3: 写者优先功能模块

图 4: 写者优先模块流程图

图

# 6 测试

稳定运行了实验报告撰写的两个小时时间。

```
[2024-12-17 23:44:31.297] Reader 3 is reading
 xmake run ReadersPriority
                                               [2024-12-17 23:44:31.297] Reader 4 is reading
[2024-12-17 21:27:21.671] Reader 1 is reading.
                                               [2024-12-17 23:44:31.297] Reader 2 is reading
[2024-12-17 21:27:21.671] Reader 2 is reading.
                                               [2024-12-17 23:44:31.402] Writer 1 is writing
[2024-12-17 21:27:21.671] Reader 3 is reading.
                                               [2024-12-17 23:44:31.553] Writer 2 is writing
[2024-12-17 21:27:21.671] Reader 4 is reading.
[2024-12-17 21:27:21.671] Reader 5 is reading.
                                               [2024-12-17 23:44:31.703] Reader 1 is reading
                                               [2024-12-17 23:44:31.703] Reader 4 is reading
[2024-12-17 21:27:21.777] Writer 1 is writing.
                                               [2024-12-17 23:44:31.703] Reader 5 is reading
[2024-12-17 21:27:21.932] Writer 2 is writing.
                                               [2024-12-17 23:44:31.703] Reader 2 is reading
[2024-12-17 21:27:22.082] Reader 1 is reading.
[2024-12-17 21:27:22.082] Reader 4 is reading.
                                               [2024-12-17 23:44:31.703] Reader 3 is reading
                                               [2024-12-17 23:44:31.806] Writer 1 is writing
[2024-12-17 21:27:22.082] Reader 2 is reading.
                                               [2024-12-17 23:44:31.961] Writer 2 is writing
[2024-12-17 21:27:22.082] Reader 5 is reading.
                                               [2024-12-17 23:44:32.116] Reader 1 is reading
[2024-12-17 21:27:22.082] Reader 3 is reading.
[2024-12-17 21:27:22.187] Writer 1 is writing.
                                               [2024-12-17 23:44:32.116] Reader 2 is reading
[2024-12-17 21:27:22.338] Writer 2 is writing.
                                               [2024-12-17 23:44:32.116] Reader 4 is reading
[2024-12-17 21:27:22.490] Reader 2 is reading.
                                               [2024-12-17 23:44:32.116] Reader 5 is reading
[2024-12-17 21:27:22.491] Reader 5 is reading.
                                               [2024-12-17 23:44:32.116] Reader 3 is reading
[2024-12-17 21:27:22.491] Reader 1 is reading.
                                               [2024-12-17 23:44:32.221] Writer
```

图 5: 读者优先运行开始 图 6: 读者优先运行结束

```
[2024-12-17 23:44:28.940] Writer 1 is writing.
                                                [2024-12-17 23:44:29.092] Writer 2 is writing
                                                [2024-12-17 23:44:29.242] Reader 3 is reading.
                                                [2024-12-17 23:44:29.242] Reader 1 is reading.
                                                [2024-12-17 23:44:29.242] Reader 2 is reading.
                                                [2024-12-17 23:44:29.243] Reader 4 is reading.
                                                [2024-12-17 23:44:29.243] Reader 5 is reading.
                                                [2024-12-17 23:44:29.348] Writer 1 is writing.
                                                [2024-12-17 23:44:29.503] Writer 2 is writing.
                                                [2024-12-17 23:44:29.654] Reader 4 is reading.
  Xmake run WritersPriority
                                                [2024-12-17 23:44:29.655] Reader 5 is reading.
[2024-12-17 21:25:27.849] Reader 1 is reading.
                                                [2024-12-17 23:44:29.655] Reader 2 is reading.
[2024-12-17 21:25:27.849] Reader 2 is reading.
                                                [2024-12-17 23:44:29.655] Reader 1 is reading.
[2024-12-17 21:25:27.850] Reader 3 is reading.
                                                [2024-12-17 23:44:29.655] Reader 3 is reading.
[2024-12-17 21:25:27.850] Reader 4 is reading.
                                                [2024-12-17 23:44:29.757] Writer 1 is writing
[2024-12-17 21:25:27.850] Reader 5 is reading.
                                                [2024-12-17 23:44:29.910] Writer 2 is writing
[2024-12-17 21:25:27.954] Writer 1 is writing.
                                                [2024-12-17 23:44:30.066] Writer 1 is writing.
[2024-12-17 21:25:28.109] Writer 2 is writing.
                                                [2024-12-17 23:44:30.221] Writer 2 is writing
[2024-12-17 21:25:28.264] Writer 1 is writing.
                                                [2024-12-17 23:44:30.373] Writer 1 is writing.
[2024-12-17 21:25:28.418] Writer 2 is writing.
                                                [2024-12-17 23:44:30.528] Writer 2 is writing
[2024-12-17 21:25:28.569] Reader 4 is reading.
                                                [2024-12-17 23:44:30.684] Writer 1 is writing
```

图 7: 写者优先运行开始 图 8: 写者优先运行结束

# A 程序文档 by doxygen



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# Chapter 1

# Class Index

# 1.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

ReadersPriority	
Implements the Readers Priority solution to the Readers-Writers problem	5
WritersPriority	
Implements a Writers Priority solution to the Readers-Writers problem	9

2 Class Index

# Chapter 2

# File Index

# 2.1 File List

Here is a l	ist of all	files with	brief	descriptions
-------------	------------	------------	-------	--------------

src/ReadersPriority.cpp															 	 			1	5
src/WritersPriority.cpp															 	 			1	7

File Index

# Chapter 3

# Class Documentation

#### 3.1 ReadersPriority Class Reference

Implements the Readers Priority solution to the Readers-Writers problem.

Collaboration diagram for ReadersPriority:

#### ReadersPriority

- std::mutex mtx
- std::mutex wrt
- int read\_count
- std::mutex cout\_mtx
- + ReadersPriority() =default
- + void reader(int reader\_id)
- + void writer(int writer\_id)

#### Public Member Functions

• ReadersPriority ()=default

 ${\bf Default\ constructor.}$ 

• void reader (int reader\_id)

Function executed by reader threads.

• void writer (int writer\_id)

Function executed by writer threads.

6 Class Documentation

#### Private Attributes

• std::mutex mtx

Mutex to protect the shared counter read\_count.

• std::mutex wrt

Mutex used by writers. If locked, writers are writing (or waiting to write).

• int read count = 0

Number of active readers.

• std::mutex cout mtx

Mutex to protect output operations to std::cout.

#### 3.1.1 Detailed Description

Implements the Readers Priority solution to the Readers-Writers problem.

In this Readers Priority approach:

- Multiple readers can read concurrently if no writer is writing.
- A writer can write only if no reader is reading and no other writer is writing.
- Readers have priority: once a reader starts reading, it prevents writers from acquiring the lock until all readers have finished.

#### 3.1.2 Constructor & Destructor Documentation

#### 3.1.2.1 ReadersPriority()

```
ReadersPriority::ReadersPriority () [default]
```

Default constructor.

#### 3.1.3 Member Function Documentation

```
3.1.3.1 reader()
```

Function executed by reader threads.

Each reader enters a loop:

- Acquires a lock on mtx to safely increment read\_count.
- If this thread is the first reader (read\_count == 1), it locks wrt to block writers.
- Simulates a read operation and logs it to std::cout.
- Decrements read\_count, and if it is the last reader (read\_count == 0), unlocks wrt.
- Sleeps briefly before attempting to read again.

#### Parameters

reader_id	An integer identifier for the reader (for logging).	]
-----------	---	---

Here is the call graph for this function:



Here is the caller graph for this function:



#### 3.1.3.2 writer()

```
\begin{tabular}{ll} void Readers Priority::writer ( \\ & int writer\_id) & [inline] \end{tabular}
```

Function executed by writer threads.

Each writer enters a loop:

- Locks wrt to gain exclusive writing access.
- Simulates a write operation and logs it to std::cout.
- Unlocks wrt to allow other readers or writers.
- Sleeps briefly before attempting to write again.

#### Parameters

writer\_id An integer identifier for the writer (for logging).

Class Documentation

Here is the call graph for this function:



Here is the caller graph for this function:



#### 3.1.4 Member Data Documentation

#### 3.1.4.1 cout\_mtx

 $std::mutex\ ReadersPriority::cout\_mtx\quad [private]$ 

Mutex to protect output operations to std::cout.

#### 3.1.4.2 mtx

std::mutex ReadersPriority::mtx [private]

Mutex to protect the shared counter read\_count.

#### 3.1.4.3 read\_count

int ReadersPriority::read\_count = 0 [private]

Number of active readers.

#### 3.1.4.4 wrt

std::mutex ReadersPriority::wrt [private]

Mutex used by writers. If locked, writers are writing (or waiting to write).

The documentation for this class was generated from the following file:

• src/ReadersPriority.cpp

# 3.2 WritersPriority Class Reference

Implements a Writers Priority solution to the Readers-Writers problem.

Collaboration diagram for WritersPriority:

#### WritersPriority

- std::mutex mtx
- std::mutex wrt
- std::condition variable cond
- int read\_count
- int write count
- bool prefer\_writers
- bool wrt\_locked
- std::mutex cout\_mtx
- + WritersPriority() =default
- + void reader(int reader\_id)
- + void writer(int writer\_id)

#### **Public Member Functions**

• WritersPriority ()=default

Default constructor.

• void reader (int reader\_id)

Function executed by reader threads.

• void writer (int writer\_id)

Function executed by writer threads.

10 Class Documentation

#### Private Attributes

• std::mutex mtx

Mutex to protect shared state (e.g., counters, flags).

std::mutex wrt

Mutex used by writers. If locked, a writer is writing (or waiting to write).

• std::condition\_variable cond

Condition variable to signal state changes to waiting threads.

• int read\_count = 0

Current number of active readers.

• int write\_count = 0

Current number of writers either waiting or writing.

• bool prefer\_writers = true

Flag to indicate if the system currently prefers writers over readers.

• bool wrt\_locked = false

Indicates whether the wrt mutex is currently locked by a writer.

• std::mutex cout\_mtx

Mutex to protect output operations (e.g. writing to std::cout).

#### 3.2.1 Detailed Description

Implements a Writers Priority solution to the Readers-Writers problem.

In this Writers Priority approach:

- Writers have priority to acquire the lock over new readers.
- A writer will block incoming readers when it is waiting for or holding the write lock.

#### 3.2.2 Constructor & Destructor Documentation

#### 3.2.2.1 WritersPriority()

WritersPriority::WritersPriority () [default]

Default constructor.

#### 3.2.3 Member Function Documentation

```
3.2.3.1 reader()
```

```
\label{eq:condition} \begin{tabular}{ll} \begin{tabular}{ll} void Writers Priority:: reader ( & \\ & int \ reader\_id) & [inline] \end{tabular}
```

Function executed by reader threads.

Each reader enters a loop:

- · Waits while any writer is waiting.
- Increments the reader count, locking wrt if this is the first reader.
- Performs reading operations (simulated with a sleep).
- Decrements reader count, unlocking wrt if this is the last reader.
- Notifies all threads waiting on the condition variable.
- Sleeps briefly before attempting to read again.

#### Parameters

reader_id An integer identifier for the reader (for logging).
---

Here is the call graph for this function:



Here is the caller graph for this function:



#### 3.2.3.2 writer()

```
\begin{tabular}{ll} void Writers Priority::writer ( & & & \\ & int writer\_id) & [inline] \end{tabular}
```

Function executed by writer threads.

Each writer enters a loop:

- Increments the writer count.
- Waits until no readers are reading (read\_count == 0) and wrt is not locked.
- Locks wrt and sets wrt\_locked to true.
- Performs writing operations (simulated with a sleep).
- Decrements writer count, unlocks wrt, and resets wrt\_locked.
- Notifies all threads waiting on the condition variable.
- Sleeps briefly before attempting to write again.

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#### Parameters

Here is the call graph for this function:



Here is the caller graph for this function:



#### 3.2.4 Member Data Documentation

#### 3.2.4.1 cond

 $std::condition\_variable\ WritersPriority::cond\quad [private]$ 

Condition variable to signal state changes to waiting threads.

#### 3.2.4.2 cout\_mtx

 $std::mutex\ WritersPriority::cout\_mtx\quad [private]$ 

Mutex to protect output operations (e.g. writing to std::cout).

#### 3.2.4.3 mtx

std::mutex WritersPriority::mtx [private]

Mutex to protect shared state (e.g., counters, flags).

#### 3.2.4.4 prefer\_writers

 $bool\ Writers Priority::prefer\_writers = true \quad [private]$ 

Flag to indicate if the system currently prefers writers over readers.

#### 3.2.4.5 read\_count

 $int\ Writers Priority :: read\_count = 0 \quad [private]$ 

Current number of active readers.

#### 3.2.4.6 write\_count

 $int\ Writers Priority:: write\_count = 0 \quad [private]$ 

Current number of writers either waiting or writing.

#### 3.2.4.7 wrt

std::mutex WritersPriority::wrt [private]

Mutex used by writers. If locked, a writer is writing (or waiting to write).

#### 3.2.4.8 wrt\_locked

 $bool\ Writers Priority::wrt\_locked = false \quad [private]$ 

Indicates whether the wrt mutex is currently locked by a writer.

The documentation for this class was generated from the following file:

• src/WritersPriority.cpp

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# Chapter 4

# File Documentation

### 4.1 src/ReadersPriority.cpp File Reference

```
#include <chrono>
#include <iomanip>
#include <iostream>
#include <mutex>
#include <sstream>
#include <thread>
#include <vector>
Include dependency graph for ReadersPriority.cpp:
```



#### Classes

• class ReadersPriority

Implements the Readers Priority solution to the Readers-Writers problem.

#### Macros

• #define RESET " $\sqrt{033}[0m]$ "

ANSI color reset code.

• #define GREEN " $\sqrt{033[32m]}$ "

ANSI color code for green text.

• #define RED " $\sqrt{033[31m]}$ "

ANSI color code for red text.

16 File Documentation

#### Functions

• std::string current\_time ()

Retrieves the current local time in a string format with milliseconds.

• int main ()

Main function where reader and writer threads are created.

#### 4.1.1 Macro Definition Documentation

#### 4.1.1.1 GREEN

```
#define GREEN "\setminus 033[32m]"
```

ANSI color code for green text.

#### 4.1.1.2 RED

#define RED " $\sqrt{033[31m]}$ "

ANSI color code for red text.

#### 4.1.1.3 RESET

#define RESET "\033[0m"

ANSI color reset code.

#### 4.1.2 Function Documentation

#### 4.1.2.1 current\_time()

std::string current\_time ()

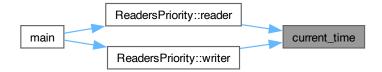
Retrieves the current local time in a string format with milliseconds.

This function uses std::chrono to get the current system time, and formats it into a string in the format YYYY-MM-DD HH:MM:SS.mmm.

#### Returns

A string representing the current local time with millisecond precision.

Here is the caller graph for this function:



```
4.1.2.2 main()
```

int main ()

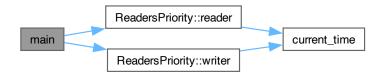
Main function where reader and writer threads are created.

Creates multiple reader threads and writer threads. Each thread runs indefinitely, demonstrating the Readers Priority approach for the Readers-Writers problem.

#### Returns

Exit code (0 for normal termination).

Here is the call graph for this function:



### 4.2 src/WritersPriority.cpp File Reference

```
#include <chrono>
#include <condition_variable>
#include <iomanip>
#include <iostream>
#include <mutex>
#include <sstream>
#include <thread>
#include <vector>
Include dependency graph for WritersPriority.cpp:
```



#### Classes

• class WritersPriority

Implements a Writers Priority solution to the Readers-Writers problem.

File Documentation

#### Macros

```
#define RESET "\033[0m"

ANSI color reset code.
#define GREEN "\033[32m"
```

ANSI color code for green text (used by readers).

• #define RED "033[31m]"

ANSI color code for red text (used by writers).

#### Functions

• std::string current\_time ()

Retrieves the current local time in a string format with milliseconds (thread-safe).

• int main ()

Main function where reader and writer threads are created.

#### 4.2.1 Macro Definition Documentation

#### 4.2.1.1 GREEN

```
#define GREEN "\sqrt{033[32m]}"
```

ANSI color code for green text (used by readers).

#### 4.2.1.2 RED

```
#define RED "\setminus 033[31m]"
```

ANSI color code for red text (used by writers).

#### 4.2.1.3 RESET

#define RESET " $\setminus 033[0m]$ "

ANSI color reset code.

#### 4.2.2 Function Documentation

#### 4.2.2.1 current\_time()

std::string current\_time ()

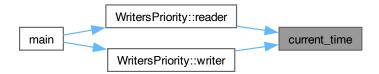
Retrieves the current local time in a string format with milliseconds (thread-safe).

This function uses std::chrono to get the current system time and formats it into a string in the format YYYY-MM-DD HH:MM:SS.mmm.

#### Returns

A string representing the current local time with millisecond precision.

Here is the caller graph for this function:



#### 4.2.2.2 main()

int main ()

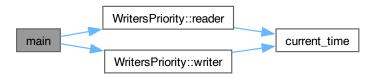
Main function where reader and writer threads are created.

Creates multiple reader threads and writer threads. Each thread runs indefinitely, demonstrating the Writers Priority approach for the Readers-Writers problem.

#### Returns

Exit code (0 for normal termination).

Here is the call graph for this function:



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