Advanced Parallel Programming Exercise 5

Marvin Kaster

TECHNISCHE UNIVERSITÄT DARMSTADT

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Please solve the following tasks by 26.06.2025. The results are not graded, but a solution is discussed on 26.06.2025.

Task 1: Implement a thread-safe array

Implement a thread-safe lock-based array. You can write a thread-safe wrapper around `std::array`. Your implementation should have the interface shown below. It shall support the concurrent writing on two different indices of the array and concurrent reading of the same index. Please do not use a global lock. Why is it not easily possible to create a thread-safe vector using the same technique?

```cpp
#include <cstddef>

template<typename T, std::size_t N>
class ThreadSafeArray {
private:

public:
    ThreadSafeArray() = default;

    ThreadSafeArray(const ThreadSafeArray &) = delete;

    ThreadSafeArray &operator=(const ThreadSafeArray &) = delete;

    void set(std::size_t index, const T &value);

    T get(std::size_t index) const;

    T operator[](std::size_t index) const;

    std::size_t size() const;

};
```

Listing 1: Thread-safe array

Task 2: Implement a thread safe queue

Implement a thread-safe lock-based queue. You can write a thread-safe wrapper around `std::queue`. Your implementation should have the interface shown below. Implement the `wait_and_pop()` method using `std::condition_variable`. What is the advantage of returning the elements with a `std::shared_ptr` instead of a copy of the value? Is there an alternative?

```cpp
#pragma once

#include <memory>

template<typename T>
class ThreadSafeQueue {

```

```
  public:
  ThreadSafeQueue() = default;

  ThreadSafeQueue(const ThreadSafeQueue &t) = delete;

  /**
  * Removes the first element of the queue and returns it if the queue is not empty
  * @return shared_ptr to the first element or null if the queue is empty
  */
  [[nodiscard]] std::shared_ptr<T> try_pop();

  /**
  * Removes the first element of the queue and returns it. If the queue is empty, this call blocks until
    at least one element is in the queue
  * @return Shared_ptr to the first element
  */
  [[nodiscard]] std::shared_ptr<T> wait_and_pop();

  /**
  * Pushes the value to the end of the queue
  * @param value The value
  */
  void push(T value);

  /**
  * Returns true if the queue is empty
  * @return True if the queue is empty
  */
  [[nodiscard]] bool empty();
};

```

Listing 2: ThreadSafeQueue.h

Task 3: Implement a thread-safe stack

Implement a thread-safe lock-based stack. You can write a thread-safe wrapper around `std::stack`. Your implementation should have the interface shown below and can throw an exception if the user attempts to `pop()` on an empty stack.

```
#include <memory>
#include <mutex>
#include <stack>


template<typename T>
class ThreadSafeStack {
private:
    std::stack<T> data{};
    mutable std::mutex mutex{};

public:

    ThreadSafeStack() = default;

    ThreadSafeStack(const ThreadSafeStack<T>& other);

    void push(T new_value);

    std::shared_ptr<T> pop();

    void pop(T &value);

    bool empty() const;

```

```
26 };
```

Listing 3: Thread-safe stack