Datenstrukturen und Algorithmen

Exercise 14 - Discussion Exercise 13

FS 2019

Program of today

1. Feedback of last exercise

1. Feedback of last exercise

Exercise 13.1: Race conditions

- Make functions of `Item` class thread safe.
- Simple approach: Get lock at beginning of function, release at the end.

Ratings

```
class Item {
private:
  int rating_sum = 0;
  int rating_count = 0;
  std::recursive_mutex mtx; // re-entrant lock for out_rating
public:
  Item() {};

  /* Returns average rating. 0 if no rating occured */
  double get_rating() {
    // minimal requirement: do not forget the lock
    std::lock_guard<std::recursive_mutex> lock(mtx);
    if(rating_count == 0) return 0.0; // some forgot this
    return (double)rating_sum / rating_count;
  }
```

Ratings

```
void add_rating(int stars){
  assert(1 <= stars && stars <= 5);
  std::lock_guard<std::recursive_mutex> lock(mtx);
  // some put the computation of the rating here,
  // which is quite clever
  rating_sum += stars;
  rating_count++;
}
```

Ratings

```
// when you do not protect this, you might run into two kind of problems:
// 1.) Inconsistent result
//     when call to add_rating between rating_count and get_rating
// 2.) scrumbled output when threads call out_rating in parallel
void out_rating(){
  std::lock_guard<std::recursive_mutex> lock(mtx); // required!
  std::cout << "ratings:" << rating_count << ", ";
  std::cout << "score:" << get_rating() << "\n";
 }
};
```

Exercise 13.2: Concurrent linked list

Coarse-grained: Analogous to first exercise

Fine-grained: Multiple locks, one per list element.

Concurrent Linked List – coarse lock

```
class LinkedList {
  ...
  Node * head ; // the head is a sentinel !!
  std::recursive_mutex mtx; // does not necessarily have to be recursive here
  ...

  void insert (T el){
    std::lock_guard<std::recursive_mutex> lock(mtx); // minimal requirement
    ...
  };
  void remove(const T val){
    std::lock_guard<std::recursive_mutex> lock(mtx); // minimal requirement
    ...
  }
```

Concurrent Linked List – fine grained lock

```
template<class T>
class LinkedList {
  private:
    struct Node {
      std::mutex mutex;
      Node *next = nullptr;
      T val;
      Node(T v) : val(v) {};
    };
  ...
```

Concurrent Linked List – insert

```
void insert (T el){
    Node * prev = head; // guaranteed to be non−null
    prev−>mutex.lock(); // lock first element
    while(prev−>next != nullptr && prev−>next−>val < el){
        Node* next = prev−>next;
        next−>mutex.lock(); // lock next −− now holding two locks
        prev−>mutex.unlock(); // unlock prev −− now holding one lock again
        prev = next;
    }
    Node * next = prev−>next; // still holding the prev lock, next cannot be deletec
    Node * new_node = new Node(el);
    new_node−>next = next;
    prev−>next = new_node; // insert
    prev−>mutex.unlock(); // release the lock
};
```

Concurrent Linked List – remove

```
void remove(const T val){
  Node* prev = head; prev->mutex.lock();
  while (prev->next != nullptr){
    Node* next = prev->next; // prev is locked
    next->mutex.lock(); // next is locked
    if (next->val == val){ // prev and next both locked
      prev->next = next->next; // remove
      next->mutex.unlock(); // unlock both
      prev->mutex.unlock(); return;
    }
    prev->mutex.unlock(); // prev is unlocked
    prev = next; // now prev is next (and locked)
  }
  prev->mutex.unlock();
}
```

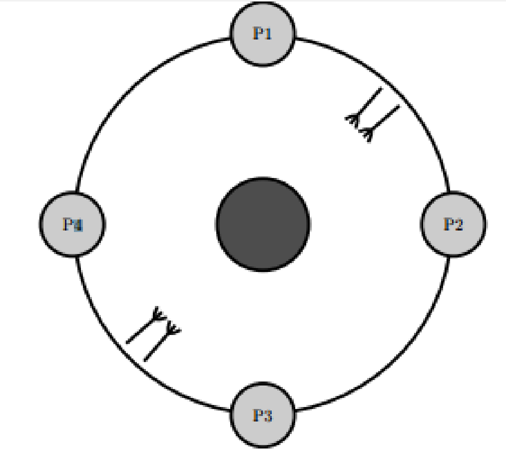
What is the advantage?

- Performance loss!
- Threads still block each other because a thread cannot traverse the list when items are locked in between.
- Other option: Optimistic and lazy-locking (not covered here).

13.3. Dining Philosophers

- To avoid deadlocks, break cyclic dependency. As discussed last time.
- Max/Min numbers of philosophers eating concurrently?
- It's possible that only one philosopher eats.

Bundle forks! Then always two can eat.



13.4. Bridge

Ensure that at most three cars or one truck is on the bridge

Use condition variable and a counter

Bridge

```
class Bridge {
    public:
        std::mutex mtx;
        std::condition_variable cv;

        int car_count = 0;

        void check_bridge(){
            if(car_count > 3){
                std::cout << "Bridge collapsed!" << std::endl;
                exit(0);
            }
        }
```

Bridge

```
void enter_car(){
    std::unique_lock<std::mutex> lock(mtx);
    cv.wait(lock, [&]{return car_count < 3;});
    car_count++;
    check_bridge();
}

void leave_car(){
    std::lock_guard<std::mutex> lock(mtx);
    car_count--;
    cv.notify_all();
}
```

Bridge

```
    void enter_truck(){
        std::unique_lock<std::mutex> lock(mtx);
        cv.wait(lock, [&]{return car_count == 0;});
        car_count += 3;
        check_bridge();
    }

    void leave_truck(){
        std::lock_guard<std::mutex> lock(mtx);
        car_count -= 3;
        cv.notify_all();
    }
};
```

Problem with this Approach?

What happens if there are cars and trucks waiting at the bridge?

Problem with this Approach?

What happens if there are cars and trucks waiting at the bridge?

The trucks do not make progress because cars.

Problem with this Approach?

What happens if there are cars and trucks waiting at the bridge?

The trucks do not make progress because cars.

Solution?

Problem with this Approach?

What happens if there are cars and trucks waiting at the bridge?

The trucks do not make progress because cars.

Solution? **Prohibt convoys:** Admit cars only if there is no truck waiting and less than 3 cars (and no truck) on the bridge or there are no cars on the bridge.

The fairness is reduced to the fairness of scheduling by the runtime system.

Fairness

```
class Bridge {
  std::mutex mtx;
  std::condition_variable cv;

  int car_count = 0; // count car equivalence
  int trucks_waiting = 0; // count trucks waiting
public:
```

Fairness

```
void enter_car(){
  std::unique_lock<std::mutex> lock(mtx);
  cv.wait(lock, [&]{
      return (car_count < 3)
            && (trucks_waiting == 0 || car_count == 0);}
  );
  car_count++;
  check_bridge();
}

void leave_car(){
  std::lock_guard<std::mutex> lock(mtx);
  car_count--;
  cv.notify_all();
}
```

Fairness

```
  void enter_truck(){
    std::unique_lock<std::mutex> lock(mtx);
    trucks_waiting++;
    cv.wait(lock, [&]{return car_count = 0;});
    trucks_waiting--;
    car_count += 3;
    check_bridge();
  }

  void leave_truck(){
    std::lock_guard<std::mutex> lock(mtx);
    car_count -= 3;
    cv.notify_all();
  }
};
```