

CS2310 Modern Operating System Exercises Spring 2023

Exercise 2: Process Synchronization

Due date: Mar. 10, 2023

1. You are designing a data structure for efficient dictionary lookup in a multithreaded application. The design uses a hash table that consists of an array of pointers each corresponding to a hash bin. The array has 1001 elements, and a hash function takes an item to be searched and computes an entry between 0 and 1000. The pointer at the computed entry is either null, in which case the item is not found, or it points to a doubly linked list of items that you would search sequentially to see if any of them matches the item you are searching for. There are three functions defined on the hash table: Insertion (if an item is not there already), Lookup (to see if an item is there), and deletion (to remove an item from the table). Considering the need for synchronization, would you:

- a. Use a mutex over the entire table?
- b. Use a mutex over each hash bin?
- c. Use a mutex over each hash bin and a mutex over each element in the doubly linked list?

Please justify your answer.

2. You have been hired by Large-Concurrent-Systems-R-Us, Inc. to review their code. Below is their `atomic_swap` procedure. It is intended to work as follows:
 - a. `Atomic_swap` should take two queues as arguments, dequeue an item from each, and enqueue each item onto the opposite queue. If either queue is empty, the swap should fail and the queues should be left as they were before the swap was attempted. The swap must appear to occur atomically – an external thread should not be able to observe that an item has been removed from one queue but not pushed onto the other one. In addition, the implementation must be concurrent – it must allow multiple swaps between unrelated queues to happen in parallel. Finally, the system should never deadlock.
 - b. Please discuss whether the following implementation is correct. If not, explain why (there may be more than one reason) and rewrite the code, such that it can work correctly. Assume that you have access to enqueue and dequeue operations on queues with the signatures given in the code. You may assume that `q1` and `q2` never refer to the same queue. You may add additional fields to stack if you document what they are.

```
extern Item *dequeue(Queue *);    // pops an item from a stack
extern void enqueue(Queue *, Item *); // pushes an item onto a stack
void atomic_swap(Queue *q1, Queue *q2) {
    Item *item1;
    Item *item2; // items being transferred
    wait(q1->lock);
    item1 = pop(q1);
    if(item1 != NULL) {
        wait(q2->lock);
        item2 = pop(q2);
        if(item2 != NULL) {
```

```

        push(q2, item1);
        push(q1, item2);
        signal(q2->lock);
        signal(q1->lock);
    }
}
}

```

3. A club has a lounge where the members can sit and chat. Members include both smokers and non-smokers. Smokers can smoke in the lounge when non-smokers are absent. Device a protocol for the lounge. A smoker calls enter Lounge (true) to enter the lounge (the flag true indicates that she is a smoker), then calls smoke(), and finally calls leave Lounge(true) to leave the lounge. Similarly, a non-smoker calls enter Lounge (false) to enter, then sits in the lounge and chats with others, and finally calls leave Lounge (false) to leave the lounge.

Questions:

- a. Declare all the variables/arrays you need for this problem and initialize them.
- b. Declare all the semaphores needed for synchronization and mutual exclusion you need for this problem and initialize them.
- c. Write pseudo code for the functions noted above so that smoking rules are obeyed.

4. Search-Insert-Delete Problem

Three kinds of processes share access to a data structure: searchers, inserter, and deleters. Searchers access the list without changing it. So, any number of concurrent searchers can be accessing the structure safely. Inserters have the ability to add new elements to the end of the structure. Only one inserter can access the structure at any given time, but can work concurrently with any number of searchers. Lastly, Deleters can remove items from any position in the structure. As such, any deleter demands exclusive access to the structure. So, while a deleter has access to the structure neither any other deleter, any inserter, nor any searcher is allowed access.

- a. Declare all the variables/arrays you need for this problem and initialize them.
- b. Declare all the semaphores needed for synchronization and mutual exclusion you need for this problem and initialize them.
- c. Write the pseudo code for this problem to prevent starvation.