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Dpto. de Lenguajes y Ciencias de la Computación

Programación de Sistemas y Concurrencia

1st Official Exam. Course 2021-2022
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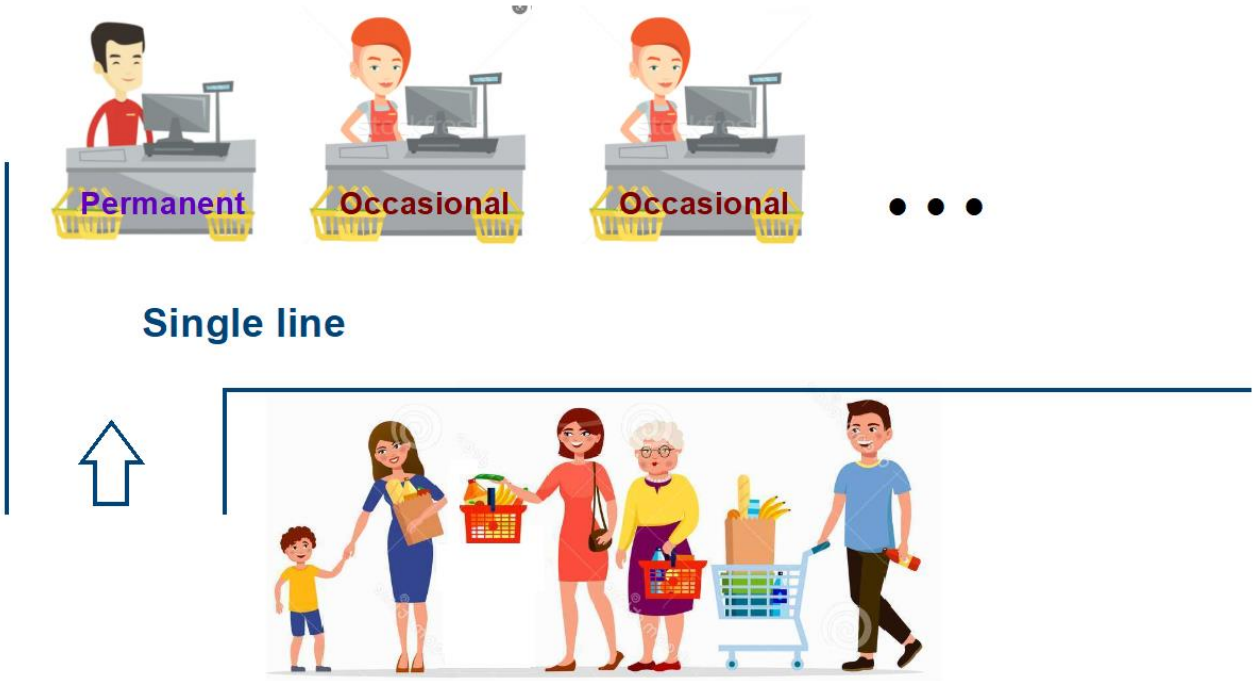
Description of the system

A **Supermarket** wants to serve their **Customers** with good quality. To do that, they have a permanent **Shopkeeker** in the line of checkout as well as occasional shopkeepers added upon demand.



In particular, when the number of Customers exceeds three times the number of Shopkeepers, then a new occasional Shopkeeper is created; and when an occasional Shopkeeper finds no Customers waiting then s/he gets out automatically. There is no limit in the number of Shopkeepers working in the Supermarket; and either Shopkeepers and Customers are represented by Threads. In addition, when the supermarket closes, all customers already created must be served and, finally, all the remaining Shopkeepers finish their work, including the permanent one. To model this, the next classes are given:

- **Customer**. It is a class that inherits from Thread and models the behaviour of a single customer. The run() function of this class "enters" into the supermarket and, when served, it finishes.
- **ShopKeeper**. It is a class that inherits from Thread and models the behaviour of a shopkeeper, either the permanent one or an occasional one. It provides the function getNumShopKeepers() that return how many "alive" shopkeepers there are currently in the checkout line. Its run() function works until there is no customer to serve.
- **Supermarket**. It is a class that models the shared resource. When this object is created, the permanent shopkeeper is also created. This shared resource provides the next methods that must be implemented by the student:

- `public void close()`: a function called by the **Driver** when the system must end to serve the remaining customers already created and, then, indicate to any remaining shopkeeper that s/he has to finish.
- `public void arrivesCustomer()`: the **Customer** uses this method to simulate that a new customer needs to be served. If the permanent shopkeeper is idle, then s/he must be woken up to serve immediately such a customer; otherwise, if the number of customers exceeds three times the current number of shopkeepers, then a new occasional ShopKeeper must be created. In any case, the customer "waits" to be served.
  When a new ShopKeeper must be created, this function calls to the constructor of the class **ShopKeeper** and starts it.
- `public boolean takeAnother(boolean permanent, int id)`: a shopkeeper, either permanent or occasional, calls this function to serve another customer.
  If the shopkeeper is occasional (parameter **permanent** is **false**) and there is no more customers, then returns **false** to indicate that such a shopkeeper is not needed any more; if there is any waiting customer then **true** is returned and a customer is immediately served.
  If the shopkeeper is permanent (parameter **permanent** is **true**) and there is any waiting customer then **true** is returned and a customer is immediately served. If not, then this shopkeeper must wait for a new customer to be available or the supermarket to close; **false** is returned only when no customer must be served and the supermarket has closed.
  Finally, note that there is no problem if the customers are not be served in order.

In addition, there is a class **Driver** containing a main() function that creates the Supermarket and, progressively, the Customers; finally, it closes the supermarket when the "day finishes".

Please, note that this exercise has only two synchronization conditions:

1. CS-Permanent. The permanent shopkeeper must wait if there is no customer to be served and the supermarket is not closed.
2. CS-Customer. The customer waits to be served by an available shopkeeper.

You have to develop two implementations of the Supermarket class, one of type 1 and another of type 2:

Type 1: General semaphores (5 pts.).

Type 2: Monitors or Locks (5 pts.).

A possible trace of the program may be ("Permanent" and "Shopkeeper 0" are the same):

```
Created Permanent shopkeeper with id: 0
Permanent waits
New client with id 1 arrives. Total customers: 1. Current waiting: 1.
Permanent starts serving a customer. Total customers served: 1
A client with id 1 exits
New client with id 2 arrives. Total customers: 2. Current waiting: 1.
Permanent starts serving a customer. Total customers served: 2
A client with id 2 exits
New client with id 3 arrives. Total customers: 3. Current waiting: 1.
New client with id 4 arrives. Total customers: 4. Current waiting: 2.
```

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```
New client with id 5 arrives. Total customers: 5. Current waiting: 3.
Permanent starts serving a customer. Total customers served: 3
A client with id 3 exits
New client with id 6 arrives. Total customers: 6. Current waiting: 3.
New client with id 7 arrives. Total customers: 7. Current waiting: 4.
Creating new shopkeeper with id: 1
Shopkeeper 1 starts serving a customer. Total customers served: 4
A client with id 5 exits
New client with id 8 arrives. Total customers: 8. Current waiting: 4.
New client with id 9 arrives. Total customers: 9. Current waiting: 5.
Shopkeeper 1 starts serving a customer. Total customers served: 5
A client with id 7 exits
New client with id 10 arrives. Total customers: 10. Current waiting: 5.
Permanent starts serving a customer. Total customers served: 6
A client with id 9 exits
New client with id 11 arrives. Total customers: 11. Current waiting: 5.
New client with id 12 arrives. Total customers: 12. Current waiting: 6.
New client with id 13 arrives. Total customers: 13. Current waiting: 7.
Creating new shopkeeper with id: 2
Shopkeeper 2 starts serving a customer. Total customers served: 7
A client with id 10 exits
New client with id 14 arrives. Total customers: 14. Current waiting: 7.
Permanent starts serving a customer. Total customers served: 8
A client with id 13 exits
Shopkeeper 1 starts serving a customer. Total customers served: 9
A client with id 14 exits
New client with id 15 arrives. Total customers: 15. Current waiting: 6.
New client with id 16 arrives. Total customers: 16. Current waiting: 7.
New client with id 17 arrives. Total customers: 17. Current waiting: 8.
Shopkeeper 2 starts serving a customer. Total customers served: 10
A client with id 12 exits
Permanent starts serving a customer. Total customers served: 11
A client with id 17 exits
Shopkeeper 1 starts serving a customer. Total customers served: 12
A client with id 11 exits
New client with id 18 arrives. Total customers: 18. Current waiting: 6.
New client with id 19 arrives. Total customers: 19. Current waiting: 7.
Shopkeeper 2 starts serving a customer. Total customers served: 13
A client with id 16 exits
New client with id 20 arrives. Total customers: 20. Current waiting: 7.
Permanent starts serving a customer. Total customers served: 14
A client with id 19 exits
Shopkeeper 1 starts serving a customer. Total customers served: 15
A client with id 20 exits
New client with id 21 arrives. Total customers: 21. Current waiting: 6.
Shopkeeper 2 starts serving a customer. Total customers served: 16
A client with id 18 exits
New client with id 22 arrives. Total customers: 22. Current waiting: 6.
Permanent starts serving a customer. Total customers served: 17
A client with id 21 exits
New client with id 23 arrives. Total customers: 23. Current waiting: 6.
Shopkeeper 1 starts serving a customer. Total customers served: 18
A client with id 22 exits
New client with id 24 arrives. Total customers: 24. Current waiting: 6.
Shopkeeper 2 starts serving a customer. Total customers served: 19
A client with id 23 exits
Permanent starts serving a customer. Total customers served: 20
A client with id 24 exits
New client with id 25 arrives. Total customers: 25. Current waiting: 5.
```

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```
Shopkeeper 1 starts serving a customer. Total customers served: 21
A client with id 15 exits
Shopkeeper 2 starts serving a customer. Total customers served: 22
A client with id 25 exits
New client with id 26 arrives. Total customers: 26. Current waiting: 4.
Permanent starts serving a customer. Total customers served: 23
A client with id 6 exits
Shopkeeper 1 starts serving a customer. Total customers served: 24
A client with id 26 exits
New client with id 27 arrives. Total customers: 27. Current waiting: 3.
Shopkeeper 2 starts serving a customer. Total customers served: 25
A client with id 4 exits
Permanent starts serving a customer. Total customers served: 26
A client with id 27 exits
Shopkeeper 1 starts serving a customer. Total customers served: 27
A client with id 8 exits
New client with id 28 arrives. Total customers: 28. Current waiting: 1.
Shopkeeper 2 starts serving a customer. Total customers served: 28
A client with id 28 exits
Permanent waits
Shopkeeper 1 gets out.
Shopkeeper 2 gets out.
New client with id 29 arrives. Total customers: 29. Current waiting: 1.
Permanent starts serving a customer. Total customers served: 29
A client with id 29 exits
Permanent waits
New client with id 30 arrives. Total customers: 30. Current waiting: 1.
Permanent starts serving a customer. Total customers served: 30
A client with id 30 exits
New client with id 31 arrives. Total customers: 31. Current waiting: 1.
New client with id 32 arrives. Total customers: 32. Current waiting: 2.
New client with id 33 arrives. Total customers: 33. Current waiting: 3.
Permanent starts serving a customer. Total customers served: 31
A client with id 31 exits
New client with id 34 arrives. Total customers: 34. Current waiting: 3.
New client with id 35 arrives. Total customers: 35. Current waiting: 4.
Creating new shopkeeper with id: 3
Shopkeeper 3 starts serving a customer. Total customers served: 32
A client with id 33 exits
New client with id 36 arrives. Total customers: 36. Current waiting: 4.
New client with id 37 arrives. Total customers: 37. Current waiting: 5.
Permanent starts serving a customer. Total customers served: 33
A client with id 35 exits
New client with id 38 arrives. Total customers: 38. Current waiting: 5.
New client with id 39 arrives. Total customers: 39. Current waiting: 6.
Shopkeeper 3 starts serving a customer. Total customers served: 34
A client with id 37 exits
New client with id 40 arrives. Total customers: 40. Current waiting: 6.
Permanent starts serving a customer. Total customers served: 35
A client with id 39 exits
New client with id 41 arrives. Total customers: 41. Current waiting: 6.
Shopkeeper 3 starts serving a customer. Total customers served: 36
A client with id 40 exits
New client with id 42 arrives. Total customers: 42. Current waiting: 6.
New client with id 43 arrives. Total customers: 43. Current waiting: 7.
Creating new shopkeeper with id: 4
Shopkeeper 4 starts serving a customer. Total customers served: 37
A client with id 41 exits
Permanent starts serving a customer. Total customers served: 38
```

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```
A client with id 43 exits
Closing the supermarket. Only serving already created customers.
New client with id 44 arrives. Total customers: 44. Current waiting: 6.
Shopkeeper 3 starts serving a customer. Total customers served: 39
A client with id 44 exits
Permanent starts serving a customer. Total customers served: 40
A client with id 34 exits
Shopkeeper 4 starts serving a customer. Total customers served: 41
A client with id 38 exits
Shopkeeper 3 starts serving a customer. Total customers served: 42
A client with id 32 exits
Permanent starts serving a customer. Total customers served: 43
A client with id 42 exits
Shopkeeper 4 starts serving a customer. Total customers served: 44
A client with id 36 exits
Shopkeeper 4 gets out.
Shopkeeper 3 gets out.
Permanent waits
Shopkeeper 0 gets out.
```

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