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TDA384
Lab1: Trainspotting

Lab1

We have implemented a solution where the trains are controlled using sensors and semaphores to avoid collisions. Each train runs in its own thread. When a train passes a sensor, a command is sent that can: stop/start the train, toggle a switch, set or release semaphores.
By blocking critical sections with semaphores, we ensure that two trains never can occupy the same critical area at the same time.
We have divided the track into 9 different semaphores, which are:

- intersection
- topTop
- topBottom
- middleTop
- middleBottom
- bottomTop
- bottomBottom
- rightSide
- leftSide

Each semaphore is connected to multiple sensors. When a train passes a sensor marking the start of an area, it attempts to lock that semaphore. If locking is not possible, the train stops until the area becomes free. If the train is able to lock the semaphore, it continues driving. When the train leaves the area, the semaphore is released.
The sensors are placed so that: all entrances and exits to the critical areas are covered, trains can be stopped well in time before a potential collision, and trains can brake safely even at maximum speed. There are also sensors placed at each side of both stations, so that the trains are able to stop and turn around after arriving at a station.
The placement is shown on the attached map, where both sensors and semaphores are marked with the same names as in the code.

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Description of critical sections

intersection

This is the crossing where tracks from topTop, topBottom, and the upper station meet. Only one train at a time can occupy the intersection. A semaphore is acquired when a train approaches from any direction and released when it leaves. The semaphore uses the fair option, so trains enter the intersection in the order they arrive. This guarantees no collisions and ensures that even if multiple trains approach simultaneously, each train waits for the previous train to fully clear the intersection. This is a natural critical section because multiple tracks meet here, and simultaneous entry would cause a collision. Protecting this intersection ensures safe and orderly passage.

topTop

The upper right track section between two sensors, containing a switch. When a train moves downward, it acquires the rightSide semaphore, toggles the switch to the right, and releases the topTop semaphore once it has passed. When moving upward, it releases the rightSide semaphore after leaving this section. This prevents collisions with trains approaching via rightSide. This section is critical because it shares the switch with topBottom and connects to rightSide. Without a semaphore, two trains could collide or block each other while using the switch.

topBottom

The lower section of the upper loop, sharing the same switch as topTop. When a train moves downward, it acquires the rightSide semaphore, toggles the switch to the left, and releases the topBottom semaphore after passing. When moving upward, it releases the rightSide semaphore. This ensures that no two trains can enter rightSide simultaneously. This is critical because it shares the same switch as topTop. Protecting it prevents simultaneous access to rightSide and avoids collisions at the switch.

middleTop

The upper part of the middle track. When a train enters from leftSide or rightSide, it acquires the corresponding semaphore to prevent other trains from entering the middle section. Once the train passes to the next section, the semaphore is released. Switches are toggled according to the train’s direction to guide it safely. This is critical because it connects leftSide and rightSide paths. Without a semaphore, trains from opposite directions could meet mid-track, causing a collision.

middleBottom
The lower part of the middle track. Functions similarly to middleTop. A train locks the corresponding side semaphore upon entry and releases it when leaving, with track switches set depending on the train's direction. This prevents conflicts on the lower middle path. This is critical for the same reason as middleTop: it allows opposing trains to potentially collide on the lower path.

bottomTop
The upper section of the lowest track, containing a switch. When a train moves upward, it acquires the leftSide-semaphore, releases bottomTop, and toggles the switch to the left. When moving downward, it releases the leftSide-semaphore. This prevents encounters between trains coming from the middle section and the bottom station. This is critical because it connects the bottom station with the middle section, and opposing trains could meet at the switch.

bottomBottom
The lower section of the lowest track, also containing a switch. When a train moves upward, it acquires the leftSide-semaphore, releases bottomBottom, and toggles the switch to the right. When moving downward, it releases the leftSide-semaphore. It blocks the opposite direction compared to bottomTop. This is critical because it blocks trains moving in opposite directions, preventing collisions at the switch and along the lowest track.

leftSide
The left outer track connects bottomTop/bottomBottom to middleTop/middleBottom. Only one train at a time can occupy this section. A train acquires the appropriate semaphore on approach from the station and releases it after moving toward the middle. The switch is selected based on which semaphore is free to prevent conflicts. This is critical because multiple trains can attempt to enter or leave via the station simultaneously. Protecting this section prevents trains from meeting on the same track.

rightSide
The right outer track connects topTop/topBottom to middleTop/middleBottom. Functions the same as leftSide: one train at a time, semaphore acquire on entry, and release on exit. Switches are chosen dynamically depending on which critical section (topTop or topBottom) is available. This is critical for the same reason as leftSide: it ensures only one train occupies the track at a time, avoiding head-on collisions.

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Maximum speed

The maximum speed for a train on our track is 19. If the speed is greater than 19, the braking distance becomes too long for the placement of our sensors. If we wanted to increase the speed, we would need to move the sensors further away from each critical point. However, this would mean that trains running at lower speeds would need to stop unnecessarily early. And graphically it can also be justified by the fact that slower trains that stop quickly might not appear to be at the station when turning around.

Testing

We tested the program by running several different simulations in the simulator at various speed combinations (19, 2), (19, 19), (10, 10), (4, 8), etc. This allowed us to ensure that the trains work well at both equal and unequal speeds. Each test was run for a long duration (at least 30 minutes) to cover as many different cases as possible.