

## **User's Guide: Traffic Simulation Program**

### **Overview**

The Traffic Simulation Program is designed to display time, traffic signals, car position and speed, and other information for traffic analysts to utilize in their work. The system has been designed to be extremely flexible and allows an unlimited number of signals and cars to be created within the parameters of the CMSC 335 Final.pdf document.

### **Setup**

#### **Prerequisites:**

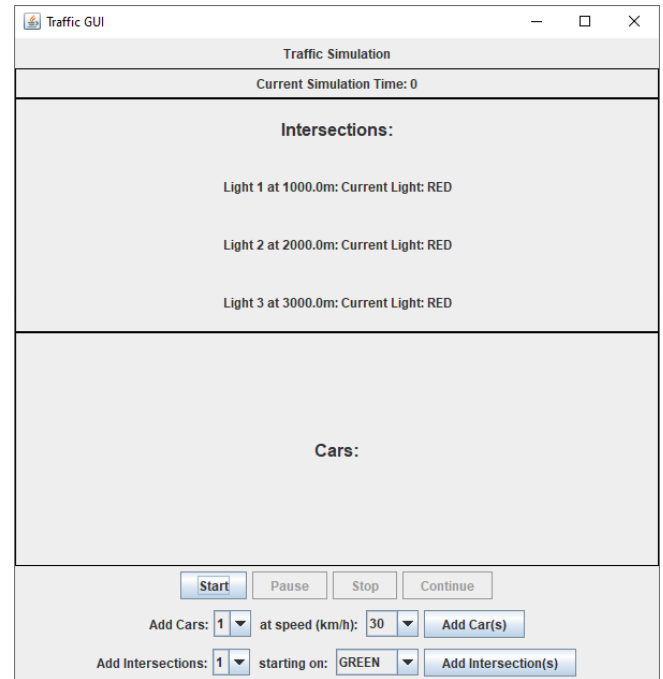
Ensure you have a Java Development Kit (JDK) installed, preferably JDK 8 or above.

#### **Steps:**

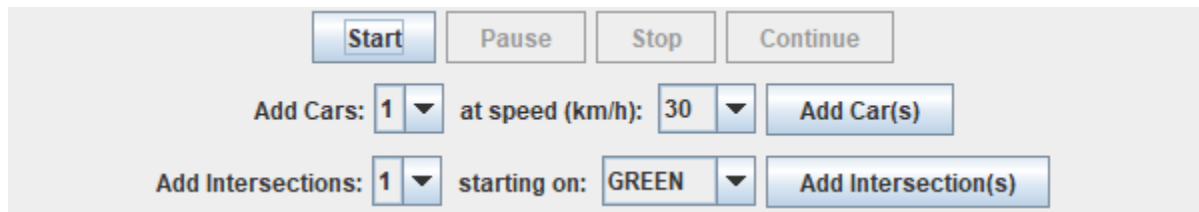
1. Download the Traffic Simulation Application source files.
2. Store them in a directory of your choice.
3. Using your preferred Java IDE (e.g., Eclipse, IntelliJ IDEA), import the files into a new Java project.

## Running the Application

Launch TrafficSimulator.java and an GUI will open up (as seen on the right).



There are three sets of controls:



1. **Simulation Controls:** These buttons allow you to Start, Pause, Stop, and Continue (unpause) the simulation. The buttons will become grayed out if they are unusable at the current simulation state.

2. **Add Car Controls:** This panel allows you to add between 1 and 3 cars each going between 30 to 210 km/h to the simulation. All cars will start at (0,0) and will move while the simulation is running, stopping at red lights.

3. **Add Intersection Controls:** This panel allows you to add between 1 and 3 intersections each 1000m farther than the last. You may also choose a starting active

light (Green, Yellow, or Red) for the created lights. All lights will switch from Green to Yellow to Red while the simulation is running.

While the simulation is running, you may utilize the Intersections and Cars panels to view real-time information on the objects of interest.

Traffic Simulation
Current Simulation Time: 16
<b>Intersections:</b>  Light 1 at 1000.0m: Current Light: GREEN  Light 2 at 2000.0m: Current Light: GREEN  Light 3 at 3000.0m: Current Light: GREEN  Light 4 at 4000.0m: Current Light: RED  Light 5 at 5000.0m: Current Light: GREEN
<b>Cars:</b>  Car 1 is at X: 800.0m and Y: 0.0 going 180.0km/h  Car 2 is at X: 450.0m and Y: 0.0 going 180.0km/h  Car 3 is at X: 233.33m and Y: 0.0 going 210.0km/h  Car 4 is at X: 25.0m and Y: 0.0 going 30.0km/h

### Design Philosophy and Class Explanation:

**Philosophy:** This program utilizes a “Model-View-Controller” (MVC) design where the Controller object acts as an intermediary between the GUI (View) and calculation class (Model), taking in user actions on the GUI, sending them to the model to be calculated and then taking the changes from the model and updating the GUI.

**TrafficSimulator:** Creates the initial JFrame and creates instances for our three main classes:

**GUIDisplay:** Builds all panels within the initial JFrame and accomplishes all GUI-related logic. Displays relevant information such as simulation timestamp, intersection status,

and car information. Contains all program controls in the form of buttons and dropdowns.

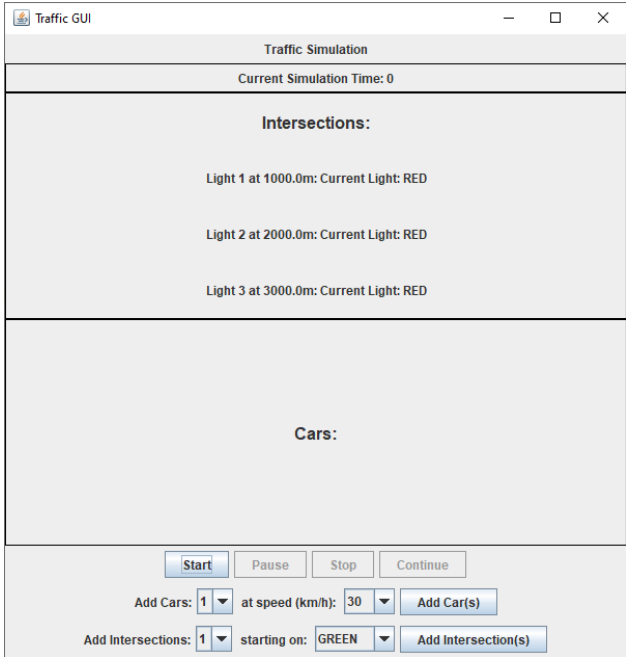
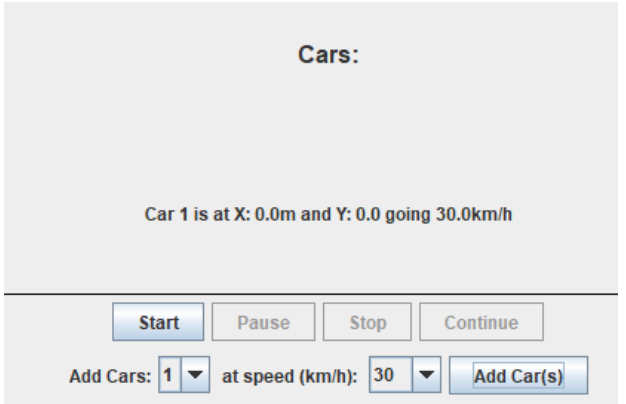
**TrafficCalculator:** Creates master ArrayLists for all TrafficLight and Car objects that are existent within the simulation. Does all calculations for changing traffic lights and car movement utilizing the internal methods of those objects.

**SimulationController:** Controller object that controls the thread logic and interfaces between GUIDisplay and TrafficCalculator. Sets ActionListeners on button objects of GUIDisplay that execute anonymous and lambda functions to control the simulation playback and to add cars and new intersections to the simulation. When simulation is paused by "Pause" button, the simulation is halted without additional updates until the "Continue" button is pressed and the simulation updates normally. When simulation is stopped by "Stop" button, the simulation is reset back to the initial starting conditions upon pressing "Start".

**TrafficLight:** Object class that holds all attributes and methods needed to simulate a traffic light within the simulation

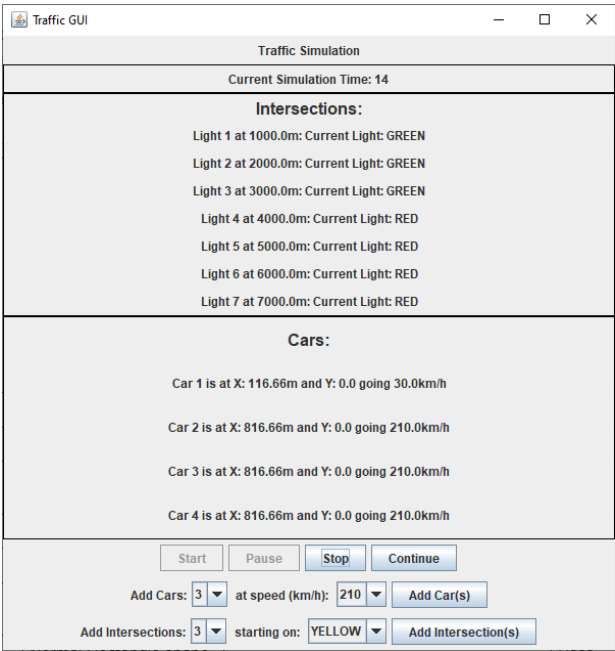
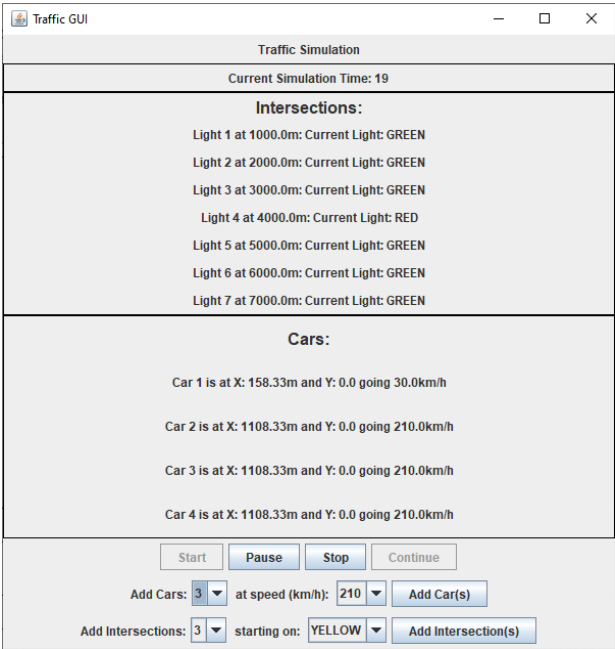
**Car:** Object class that hold all attributes and methods needed to simulate a car within the simulation.

## Testing:

Test #	Description	Screenshot	Pass/Fail
0	Start Program	 <p>The screenshot shows a window titled "Traffic GUI" with a standard Windows title bar. Inside the window, the title "Traffic Simulation" is centered. Below it, the text "Current Simulation Time: 0" is displayed. A section titled "Intersections:" contains three lines of text: "Light 1 at 1000.0m: Current Light: RED", "Light 2 at 2000.0m: Current Light: RED", and "Light 3 at 3000.0m: Current Light: RED". Below this is a large empty box labeled "Cars:". At the bottom, there are four buttons: "Start", "Pause", "Stop", and "Continue". Below the buttons, there are two rows of controls. The first row has "Add Cars:" followed by a dropdown menu showing "1", "at speed (km/h):" followed by a dropdown menu showing "30", and an "Add Car(s)" button. The second row has "Add Intersections:" followed by a dropdown menu showing "1", "starting on:" followed by a dropdown menu showing "GREEN", and an "Add Intersection(s)" button.</p>	Pass
1	Add 1 Car (30km/h)	 <p>The screenshot shows the same "Traffic GUI" window. The "Cars:" section now contains the text "Car 1 is at X: 0.0m and Y: 0.0 going 30.0km/h". The "Intersections:" section and the bottom controls remain the same as in the previous screenshot.</p>	Pass

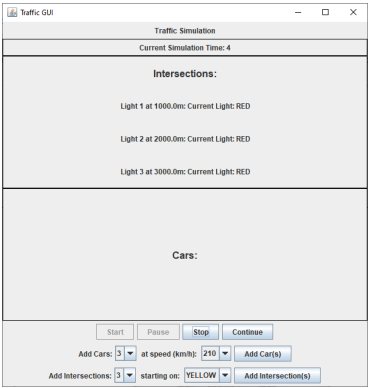
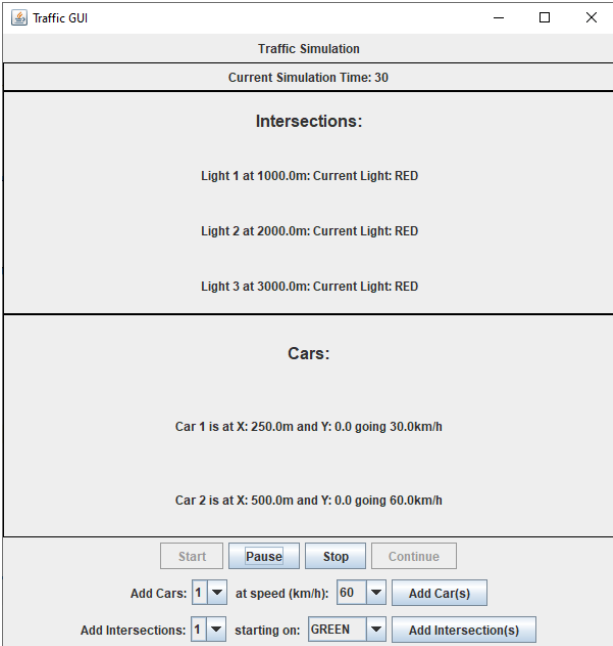
2	Add 3 Cars (210km/h)	<div>Cars:</div> <div>Car 1 is at X: 0.0m and Y: 0.0 going 30.0km/h</div> <div>Car 2 is at X: 0.0m and Y: 0.0 going 210.0km/h</div> <div>Car 3 is at X: 0.0m and Y: 0.0 going 210.0km/h</div> <div>Car 4 is at X: 0.0m and Y: 0.0 going 210.0km/h</div> <div> <div>Start</div> <div>Pause</div> <div>Stop</div> <div>Continue</div> </div> <div>Add Cars: <input type="text" value="3"/> at speed (km/h): <input type="text" value="210"/> <div>Add Car(s)</div></div>	Pass
3	Add 1 Intersection (Green)	<div>Intersections:</div> <div>Light 1 at 1000.0m: Current Light: RED</div> <div>Light 2 at 2000.0m: Current Light: RED</div> <div>Light 3 at 3000.0m: Current Light: RED</div> <div>Light 4 at 4000.0m: Current Light: GREEN</div> <div> <div>Add Intersections: <input type="text" value="1"/> starting on: <input type="text" value="GREEN"/> <div>Add Intersection(s)</div></div> </div>	Pass
4	Add 3 Intersections (Yellow)	<div>Intersections:</div> <div>Light 1 at 1000.0m: Current Light: RED</div> <div>Light 2 at 2000.0m: Current Light: RED</div> <div>Light 3 at 3000.0m: Current Light: RED</div> <div>Light 4 at 4000.0m: Current Light: GREEN</div> <div>Light 5 at 5000.0m: Current Light: YELLOW</div> <div>Light 6 at 6000.0m: Current Light: YELLOW</div> <div>Light 7 at 7000.0m: Current Light: YELLOW</div> <div> <div>Add Intersections: <input type="text" value="3"/> starting on: <input type="text" value="YELLOW"/> <div>Add Intersection(s)</div></div> </div>	Pass

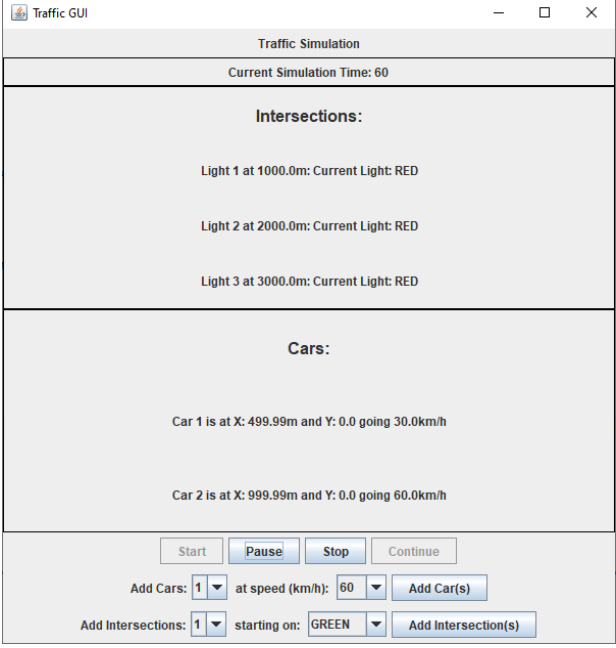
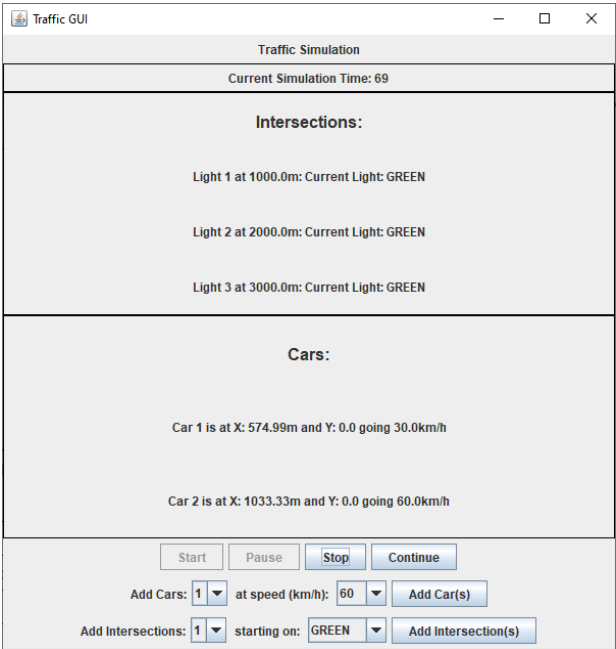
5	Start Simulation	<div><div>Traffic GUI</div><div><div>Traffic Simulation</div><div>Current Simulation Time: 7</div><div><div>Intersections:</div><div>Light 1 at 1000.0m: Current Light: RED Light 2 at 2000.0m: Current Light: RED Light 3 at 3000.0m: Current Light: RED Light 4 at 4000.0m: Current Light: GREEN Light 5 at 5000.0m: Current Light: RED Light 6 at 6000.0m: Current Light: RED Light 7 at 7000.0m: Current Light: RED</div></div><div><div>Cars:</div><div>Car 1 is at X: 58.33m and Y: 0.0 going 30.0km/h  Car 2 is at X: 408.33m and Y: 0.0 going 210.0km/h  Car 3 is at X: 408.33m and Y: 0.0 going 210.0km/h  Car 4 is at X: 408.33m and Y: 0.0 going 210.0km/h</div></div><div><div><div>Start</div><div>Pause</div><div>Stop</div><div>Continue</div></div><div>Add Cars: <div>3</div> at speed (km/h): <div>210</div> <div>Add Car(s)</div></div><div>Add Intersections: <div>3</div> starting on: <div>YELLOW</div> <div>Add Intersection(s)</div></div></div></div></div>	Pass
6	Lights Change by 12 seconds	<div><div>Traffic Simulation</div><div>Current Simulation Time: 13</div><div><div>Intersections:</div><div>Light 1 at 1000.0m: Current Light: GREEN Light 2 at 2000.0m: Current Light: GREEN Light 3 at 3000.0m: Current Light: GREEN Light 4 at 4000.0m: Current Light: YELLOW Light 5 at 5000.0m: Current Light: RED Light 6 at 6000.0m: Current Light: RED Light 7 at 7000.0m: Current Light: RED</div></div></div>	Pass

7	Simulation Pause	 <p>The screenshot shows the 'Traffic GUI' window. At the top, it says 'Traffic Simulation' and 'Current Simulation Time: 14'. Below this, there are two sections: 'Intersections:' and 'Cars:'. The 'Intersections:' section lists seven lights: Light 1 at 1000.0m (GREEN), Light 2 at 2000.0m (GREEN), Light 3 at 3000.0m (GREEN), Light 4 at 4000.0m (RED), Light 5 at 5000.0m (RED), Light 6 at 6000.0m (RED), and Light 7 at 7000.0m (RED). The 'Cars:' section lists four cars, all at X: 816.66m and Y: 0.0, going 210.0km/h. At the bottom, there are buttons for 'Start', 'Pause', 'Stop', and 'Continue'. Below these are input fields for 'Add Cars: 3' at speed '(km/h): 210' and 'Add Intersection(s): 3' starting on: 'YELLOW'.</p>	Pass
8	Simulation Continue	 <p>The screenshot shows the 'Traffic GUI' window. At the top, it says 'Traffic Simulation' and 'Current Simulation Time: 19'. Below this, there are two sections: 'Intersections:' and 'Cars:'. The 'Intersections:' section lists seven lights: Light 1 at 1000.0m (GREEN), Light 2 at 2000.0m (GREEN), Light 3 at 3000.0m (GREEN), Light 4 at 4000.0m (RED), Light 5 at 5000.0m (GREEN), Light 6 at 6000.0m (GREEN), and Light 7 at 7000.0m (GREEN). The 'Cars:' section lists four cars, all at X: 1108.33m and Y: 0.0, going 210.0km/h. At the bottom, there are buttons for 'Start', 'Pause', 'Stop', and 'Continue'. Below these are input fields for 'Add Cars: 3' at speed '(km/h): 210' and 'Add Intersection(s): 3' starting on: 'YELLOW'.</p>	Pass



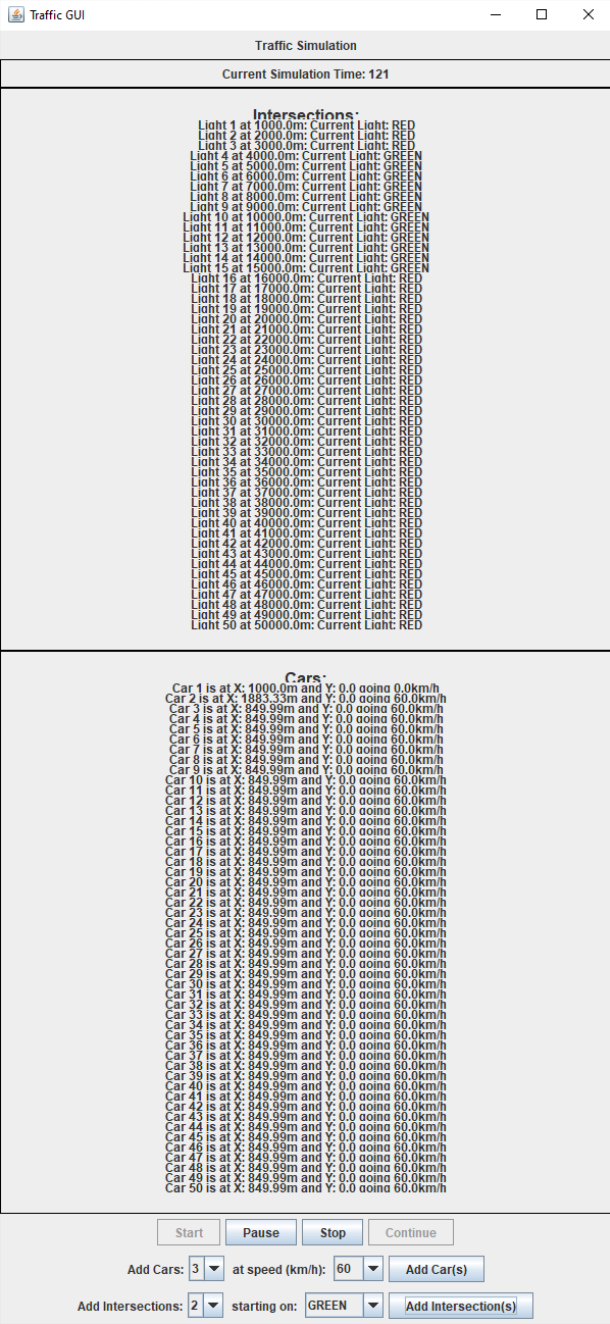
9	Cars stop at red light location (Top: Before reaching red light; Bottom: Stopped at red light)	<div><div><div>Traffic GUI</div><div><div>Traffic Simulation</div><div>Current Simulation Time: 33</div><div>Intersections: Light 1 at 1000.0m: Current Light: RED Light 2 at 2000.0m: Current Light: RED Light 3 at 3000.0m: Current Light: RED Light 4 at 4000.0m: Current Light: GREEN Light 5 at 5000.0m: Current Light: RED Light 6 at 6000.0m: Current Light: RED Light 7 at 7000.0m: Current Light: RED</div><div>Cars:  Car 1 is at X: 275.0m and Y: 0.0 going 30.0km/h  Car 2 is at X: 1924.99m and Y: 0.0 going 210.0km/h  Car 3 is at X: 1924.99m and Y: 0.0 going 210.0km/h  Car 4 is at X: 1924.99m and Y: 0.0 going 210.0km/h</div><div><div>Start</div><div>Pause</div><div>Stop</div><div>Continue</div></div><div>Add Cars: <input type="text" value="3"/> at speed (km/h): <input type="text" value="210"/> <div>Add Car(s)</div></div><div>Add Intersections: <input type="text" value="3"/> starting on: <input type="text" value="YELLOW"/> <div>Add Intersection(s)</div></div></div></div><div><div>Traffic GUI</div><div><div>Traffic Simulation</div><div>Current Simulation Time: 35</div><div>Intersections: Light 1 at 1000.0m: Current Light: RED Light 2 at 2000.0m: Current Light: RED Light 3 at 3000.0m: Current Light: RED Light 4 at 4000.0m: Current Light: GREEN Light 5 at 5000.0m: Current Light: RED Light 6 at 6000.0m: Current Light: RED Light 7 at 7000.0m: Current Light: RED</div><div>Cars:  Car 1 is at X: 291.66m and Y: 0.0 going 30.0km/h  Car 2 is at X: 2000.0m and Y: 0.0 going 0.0km/h  Car 3 is at X: 2000.0m and Y: 0.0 going 0.0km/h  Car 4 is at X: 2000.0m and Y: 0.0 going 0.0km/h</div><div><div>Start</div><div>Pause</div><div>Stop</div><div>Continue</div></div><div>Add Cars: <input type="text" value="3"/> at speed (km/h): <input type="text" value="210"/> <div>Add Car(s)</div></div><div>Add Intersections: <input type="text" value="3"/> starting on: <input type="text" value="YELLOW"/> <div>Add Intersection(s)</div></div></div></div></div> <td>Pass</td>	Pass
10	Simulation Stop	<div><div><div>Traffic GUI</div><div><div>Traffic Simulation</div><div>Current Simulation Time: 81</div><div>Intersections:  Light 1 at 1000.0m: Current Light: RED Light 2 at 2000.0m: Current Light: RED Light 3 at 3000.0m: Current Light: RED Light 4 at 4000.0m: Current Light: GREEN Light 5 at 5000.0m: Current Light: YELLOW Light 6 at 6000.0m: Current Light: YELLOW Light 7 at 7000.0m: Current Light: YELLOW</div><div>Cars:  Car 1 is at X: 675.0m and Y: 0.0 going 30.0km/h  Car 2 is at X: 3875.0m and Y: 0.0 going 210.0km/h  Car 3 is at X: 3875.0m and Y: 0.0 going 210.0km/h  Car 4 is at X: 3875.0m and Y: 0.0 going 210.0km/h</div><div><div>Start</div><div>Pause</div><div>Stop</div><div>Continue</div></div><div>Add Cars: <input type="text" value="3"/> at speed (km/h): <input type="text" value="210"/> <div>Add Car(s)</div></div><div>Add Intersections: <input type="text" value="3"/> starting on: <input type="text" value="YELLOW"/> <div>Add Intersection(s)</div></div></div></div></div> <td>Pass</td>	Pass

11	Reset on Simulation restart		Pass
12	Cars move at appropriate speed ( $30s = \frac{1}{2} \text{ speed}/60$ )		Pass

13	Cars move at appropriate speed ( $60s = \text{speed}/60$ )		Pass
14	Cars do not stop at yellow or green light location (Car 2 has passed Light 1 once it turned green)		Pass

15	50 Cars added	<p><b>Cars:</b></p> <p>Car 1 is at X: 633.33m and Y: 0.0 aoina 30.0km/h  Car 2 is at X: 1150.0m and Y: 0.0 aoina 60.0km/h  Car 3 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 4 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 5 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 6 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 7 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 8 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 9 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 10 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 11 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 12 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 13 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 14 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 15 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 16 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 17 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 18 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 19 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 20 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 21 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 22 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 23 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 24 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 25 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 26 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 27 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 28 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 29 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 30 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 31 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 32 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 33 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 34 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 35 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 36 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 37 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 38 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 39 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 40 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 41 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 42 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 43 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 44 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 45 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 46 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 47 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 48 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 49 is at X: 116.66m and Y: 0.0 aoina 60.0km/h  Car 50 is at X: 116.66m and Y: 0.0 aoina 60.0km/h</p>	Pass (simulation still runs)
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16	50 Lights Added	<p><b>Intersections:</b></p> <p>Light 1 at 1000.0m: Current Light: GREEN  Light 2 at 2000.0m: Current Light: GREEN  Light 3 at 3000.0m: Current Light: GREEN  Light 4 at 4000.0m: Current Light: GREEN  Light 5 at 5000.0m: Current Light: GREEN  Light 6 at 6000.0m: Current Light: GREEN  Light 7 at 7000.0m: Current Light: GREEN  Light 8 at 8000.0m: Current Light: GREEN  Light 9 at 9000.0m: Current Light: GREEN  Light 10 at 10000.0m: Current Light: GREEN  Light 11 at 11000.0m: Current Light: GREEN  Light 12 at 12000.0m: Current Light: GREEN  Light 13 at 13000.0m: Current Light: GREEN  Light 14 at 14000.0m: Current Light: GREEN  Light 15 at 15000.0m: Current Light: GREEN  Light 16 at 16000.0m: Current Light: GREEN  Light 17 at 17000.0m: Current Light: GREEN  Light 18 at 18000.0m: Current Light: GREEN  Light 19 at 19000.0m: Current Light: GREEN  Light 20 at 20000.0m: Current Light: GREEN  Light 21 at 21000.0m: Current Light: GREEN  Light 22 at 22000.0m: Current Light: GREEN  Light 23 at 23000.0m: Current Light: GREEN  Light 24 at 24000.0m: Current Light: GREEN  Light 25 at 25000.0m: Current Light: GREEN  Light 26 at 26000.0m: Current Light: GREEN  Light 27 at 27000.0m: Current Light: GREEN  Light 28 at 28000.0m: Current Light: GREEN  Light 29 at 29000.0m: Current Light: GREEN  Light 30 at 30000.0m: Current Light: GREEN  Light 31 at 31000.0m: Current Light: GREEN  Light 32 at 32000.0m: Current Light: GREEN  Light 33 at 33000.0m: Current Light: GREEN  Light 34 at 34000.0m: Current Light: GREEN  Light 35 at 35000.0m: Current Light: GREEN  Light 36 at 36000.0m: Current Light: GREEN  Light 37 at 37000.0m: Current Light: GREEN  Light 38 at 38000.0m: Current Light: GREEN  Light 39 at 39000.0m: Current Light: GREEN  Light 40 at 40000.0m: Current Light: GREEN  Light 41 at 41000.0m: Current Light: GREEN  Light 42 at 42000.0m: Current Light: GREEN  Light 43 at 43000.0m: Current Light: GREEN  Light 44 at 44000.0m: Current Light: GREEN  Light 45 at 45000.0m: Current Light: GREEN  Light 46 at 46000.0m: Current Light: GREEN  Light 47 at 47000.0m: Current Light: GREEN  Light 48 at 48000.0m: Current Light: GREEN  Light 49 at 49000.0m: Current Light: GREEN  Light 50 at 50000.0m: Current Light: GREEN</p>	Pass (simulation still runs)
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17	Screen resize fit		Pass
18	Normal Exit	<pre> *** Welcome to the Traffic Program! *** *** Thank you for using the Traffic Program! *** *** Logging out at 21:46:35 2023/10/09 ***  BUILD SUCCESS   ----- Total time: 05:27 min Finished at: 2023-10-09T21:52:01-06:00 ----- </pre>	Pass

19	ALT+F4 Exit	<pre> *** Welcome to the Traffic Program! *** *** Thank you for using the Traffic Program! *** *** Logging out at 21:52:25 2023/10/09 *** ----- BUILD SUCCESS ----- Total time: 15.728 s Finished at: 2023-10-09T21:52:40-06:00 ----- ' </pre>	Pass
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### Lessons Learned:

This was a challenge worthy of being the final project in a 300-level college course. I actually had to create this program twice: My initial attempt contained only a single major class that created the GUI, took in user inputs, and attempted to control the threads of the program. I was able to get this class to build a baseline GUI and add TrafficLight and Car objects to the ArrayLists, but thread control and a updating the GUI display for the new objects just never really worked right due to the unwieldy nature of such a mammoth class. Eventually, I decided I was going about it the wrong way, so I did some additional research on how others have tackled this problem. This lead me to the Model-View-Controller design and I immediately understood that was a better way to accomplish what I wanted to do.

When I rebuilt the program in MVC style, I was able to reuse some of my code, but the logic that controlled the interface between the new major classes had to be completely rewritten. I learned the power of encapsulation while doing this, though, because for each major class I mocked up a basic text response system to ensure each of my systems were working correctly (for instance, a println() that showed the car's position every 60 cycles at a set speed). This prototyping was an incredible tool that enabled me to actually compile and run my completed program with *no errors* the very first time I attempted. I will absolutely be planning a prototype phase like this again in the future.

Finally, I want to touch on the thread control aspect of this program. My initial attempt to assign logical items to individual threads within my single mega-class was a disaster where I was attempting to watch objects take actions and then assign the threads, but objects were getting updated at seemingly random and there was basically no interleaving or concurrency happening. Once I split the classes in the MVC and had the Controller class handle everything with threads, it was much simpler to just assign two system flags (isPaused and isRunning) and create a single intrinsic lock object (pauseLock) that were completely arbitrary to the execution. I referred back to the reading of the past two weeks many times to make sure I was utilizing these basic concepts correctly, but it made a world of difference by separating out the thread logic that way!

Overall, this is probably the most complex program I've ever written, but seeing the interplay of cars stopping at lights, lights switching on their own, and the GUI actively responding to my inputs is a real joy, so it was definitely all worth it. My main take aways are: 1. Focus on encapsulation even more than I think I need to; 2. Separate out thread logic and make it controlled by arbitrary objects, if possible; 3. Prototype out each portion of code before trying to link it all together.