LondonSW: Traffic Simulator

Violetta Avkhukova
Felix Santiago Anda Basabe
Rawan Mohammed Alrahili
Jia Liu
Yakubu Aliyu Doma

March 30, 2016

Contents

Part I
Introduction

As population grows as a result of rapid development of cities, so does the volume of traffic and congestion. Managing traffic congestion is a serious issue, and with the ever-increasing volume of traffic, this problem is expected to get worse.

A simple description of traffic congestion is given as a situation where the volume of traffic surpasses the capacity of the road. However, the Department for Transport provides a more quantifiable description of congestion as "the average delay experienced for each kilometre travelled compared to driving at speeds typical when traffic is light" [5].

A lot of attention has been given to modelling and simulation of traffic flows to determine the causes of traffic congestion, to determine the effectiveness of traffic policies, and how such road policies can be improved and also aid in the development and design of road infrastructures.

1 Problem Definition

Many strategies have been proposed and implemented with the primary objective of relieving congestion. However, these strategies have varying effects and it is not always self-evident which strategy works best for a given scenario. A straightforward strategy is to construct new roads to increase the road capacity or improve already existing roads, but this rarely serves as a long time solution.

Congestion is described as self managing, that is; as the capacity of the road increases, so does the traffic demand to fill the new capacity. This notion is described as Pigou-Knight analysis, which suggests improving road network capacity does not guarantee reduced congestion, on the contrary it can be counter-productive by making congestion worse [3, 5]. This strategy is regarded as one of the most expensive ways of dealing with congestion [5].

Traffic simulation is important because it allows very complex traffic models to be studied and analysed. In situations where evaluating analytical and numerical data is not sufficient enough, it provides a visual description, of both existing and future scenarios. Another huge importance of traffic simulation is that it enables us see the outcome changes to road infrastructure will have.

2 Project Summary

In this report, we give a detailed documentation of the process involved in developing a traffic simulation software. Our traffic simulation software consist of two parts: the simulation environment and the map builder.

The first part of the system is the simulation environment where actual simulations run. This part allows a user to load a map and run a simulation on it with some number of vehicles.

The second part of the system is the map making mode. This part of our system allows the user to create a map. It serves as an interface which provides all the necessary functionalities for designing road infrastructure (i.e lanes, intersections), which can then be parsed, loaded and executed in the simulation environment.

The rest of this report is structured as follows. In section 2, we review the various literature related to traffic simulation. Furthermore, we also review existing works related in this domain. We proceed to section 3 where we provide the description of our initial project requirements and the design approach we have chosen.

Part II
Review

There exists a variety of traffic simulation models which are categorised in accordance with numerous criteria, one of such criterion is the level of detail. However, within the scope of this report, only the two more general classifications are considered. These are: Macroscopic and Microscopic, which are also referred to as micro-simulation and macro-simulation. In this section, we give an analysis of the existing articles and literature related to the different classifications of traffic simulation models mentioned above.

2.1 Macroscopic

Macro-simulations use high-level mathematical models usually derived from fluid dynamics for the modelling of traffic flow [2, 4]. In this modelling approach, all vehicle are treated in the same manner (i.e individual vehicles are not modelled) however, input and output variables such as speed, density and flow are used. There is no differentiation between individual vehicles and there are usually no options of vehicle types in this approach.

Macroscopic models lack the ability of modelling complex road networks, complicated traffic features or vehicle behaviour. Therefore, they are more widely used for scenarios that do not require detailed modelling such as motorway networks [10].

2.2 Microscopic

Unlike Macro-simulations, micro-simulations model individual entities separately at a very high level of detail and are classified as discrete models. Vehicle interactions with other vehicles and the environment are tracked, where interactions are governed by car-following or lane changing logic [2]. Rules are set aside, to govern what action are permitted and what action are not permitted in the simulation. Microscopic simulations provide a more realistic modelling traffic flow compared to the macroscopic due to the ability of modelling vehicles individually. Therefore microscopic simulations are ideal in the analysis of new or existing traffic policies [2, 13].

The car-following model, also known as the time-continuous model is a categorisation of micro simulation. All car-following models are characterized using differential equations that describe the entire dynamics of vehicle positions and their velocities. This model assumes that drivers input stimuli is restricted to their own velocity, the velocity of the leading vehicle, and their distance to the leading vehicle. The driving behaviour of a vehicles in this model might not only depend on the current vehicle in front, but the number of vehicles in front [1].

Another way of implementing micrcoscopic simulations is through agent based modelling. This approach allows many scenarios to be modelled efficiently because each individual in the scenario can be represented as an agent, with a set of rules governing their behaviour. Agents can be programmed with behaviours, so as to allow individuals' behaviour to be similar to those of the entities they are modelling. Though the programmed behaviour given to agents is often simple however, when agents are simulated as a group, the often exhibit new behaviours [5]. Therefore agent based simulations are ideal for developing new models because parameters of individuals can be changed easily to observe results.

Cellular automata models are another categorization of microscopic models.The difference between the cellular automaton and the car following is that, cellular automaton is space discrete. In this model, roads are composed or series of cells, where each cell is either empty or occupied by a vehicle. Vehicle movement is restricted by the vehicle in front. That is, vehicles are only able to move forward when the next cell is unoccupied. Certain rules are defined to determine when a vehicle moves to the next cell. This method is said to be very efficient due to its simple array structure [2].

Part III
Requirements and Design

Prior to embarking on the design of the system, we researched the different traffic simulation models for better understanding of the domain, from which an appropriate model was chosen for our simulation software. In this section, we describe the requirements we set out for our project and the design choices taken to meet these requirements.

3 Requirements

To make development easier, priorities must be emphasised on the most important aspects of software. To achieve this, we hierarchically structured our aims using the MoSCoW prioritization method. This was used to classify the aims of the project into various levels of importance as presented:

1. Must
   - (a) Adopt and adhere to cellular automaton model
   - (b) Entry and exit points for vehicles
   - (c) Free movement and turning of vehicles
   - (d) Traffic light functions
   - (e) Default map
   - (f) Display simple animation of vehicle movement
2. Should
   - (a) Users' can create and save maps
   - (b) Traffic policies
   - (c) Import pre-made maps
   - (d) Control for simulation, i.e number of vehicle and simulation speed
   - (e) Prioritize emergency services
3. Could
   - (a) Statistics, i.e time spent at traffic light e.t.c
   - (b) Curve roads
   - (c) External map sources, e.g OpenStreetMap, Google Maps

Requirements under the "Must" classification are extremely important features of our system. They are the minimum building block of our simulation. That is, they are the minimum required features that must be implemented for the basic functioning of the system. Features in the next classification are also important because they provide added value to the system. However, the basic functioning of the overall system does not rely on them therefore not all features here might be present due certain constraints. Finally, the features listed on the last classification category "Could" are features which we regard to as non-functional however, if implemented provide additional functionalites.

4 Design

To design systems accurately, a correct system architecture is extremely important. It aids in ensuring that all requirement of a system are fulfilled and further helps with scalability, to meet future requirements. Our system was designed upon a simple form of microscopic traffic simulation known as the cellular automaton. This approach relies on updating vehicle positions based on a central timing clock (Ticker).

We opted for the Model-View-Controler architectural style for the design of our system. The M-V-C style allows us to separate concerns thats is, tasks are grouped into either model or view component depending on what functions they perform in the system.

The ***model*** is responsible for maintaining domain knowledge. In our case, it encapsulates the cellular automaton logic which our system must adhere to. It also notifies the *view* of changes in state. The ***view*** is responsible for displaying information to the user. It displays the logic encapsulated by the model and maps users' actions to the *controller*. Finally, the ***controller*** manages interactions with the user. That is, as no direct communication is possible from the *view* to the *model*, the *controller* therefore responsible for mapping user actions to *model* updates.

The singleton design pattern is also used for most controllers in the system. We decided use this design pattern because we only needed one instance of controller objects for manage each type of map component.

Part IV Implementation

5 Map

The Map class represents maps that the simulation runs on. Vehicles interact with the map by driving through roads that they choose. The sections below describe how this class is structured.

5.1 The Basics

There are a number of low-level basic controls that make our maps possible. They are listed and described below.

5.1.1 Coordinates

Our basic unit for positioning is the Coordinate class which contains a pair of integers which denote x- and y-positions in a two dimensional coordinate system. The former represents the vertical axis and the latter represents the horizontal axis. This class is used by the whole system in many classes, like locations of intersections, vehicles, and the start and end points of roads and lanes.

Besides the getters and setters for the x- and y- positions, the most useful features are the overloading of the equals operator to enable Coordinate comparisons, addition and subtraction methods of Coordinates and the capability to add a step to a position regarding the cardinal direction.

5.1.2 Components

There is an interface in our system called Component that acts as a common denominator between objects that we are able to add to a map. We have two types of components, Roads and Intersections, but this can be expanded to more types if necessary. The actual interface is empty, because no common functionality is necessary between all components. It is most useful for the MapGrid class, which stores the underlying map structures as a 2d-array of Components. This makes storing and looping through map components easy. Like the Coordinate, the components are used widely in the whole system. To use components, we capture the object and cast it to an instance of either a Road or an Intersection, and then we are able to interact with the component treating it as the former or the latter.

5.2 Structure

The map consists of three important components: a MapGrid instance, Roads, and Intersections. In general, a map consists of a mixture of roads and intersections that build a type of graph, where intersections are nodes and roads are directed edges between nodes. Each map has a constant width and height. The Map class has functions that allows communication with components deeper down the Map hierarchy, like Roads to Lanes to Cells.

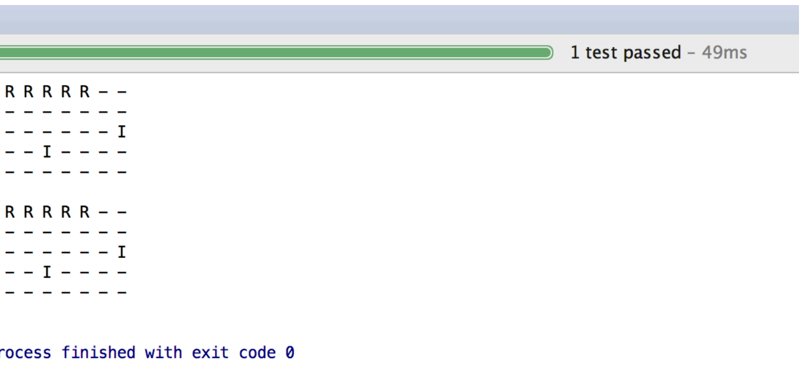
MapGrid The MapGrid class is the underlying structure of our Map. It contains a 2D-array of the Component instances, which can be Roads, Intersections or empty. The map grid has a width and height which represents the size of the map. An important method that it contains is "addComponent(Component c)" which takes a generic component and adds it to the grid structure.

Roads For more information about roads in the map, refer to section 6 on page 10.

Intersections For more information about intersections in the map, refer to section 8 on page 12.

5.3 Testing

We were able to test the model of our maps in a text-based fashion then subsequently when the relevant tests were passed, we were able to integrate it with a graphic user interface view.


1 test passed – 49ms

```
R R R R R - -
- - - - - - -
- - - - - - I
- - I - - - -
- - - - - - -

R R R R R - -
- - - - - - -
- - - - - - I
- - I - - - -
- - - - - - -


rocess finished with exit code 0
```

6 Roads

6.1 Basic Structure

A road is a container for one or more lanes with a start point and an end point of type Coordinate. Each road is connected to at most two intersections. Roads can be of size 1 to n and only can be drawn horizontally or vertically according to the start and end point locations. Our simulation system has limited the number of lanes to 2 with a left-hand driving traffic pattern. If we do not assign an intersection to the end of the road, the vehicle will leave the simulation after reaching the end.

6.2 Lanes

A lane is part of a road where the vehicles move. A lane's length is defined by the road it is in. The maximum number of cells that vehicles can be in is equal to the length of the lane. Vehicles enter the lanes at the start position and exit through the end position. Lanes are like queues that follow the cellular automata model, i.e. it is first-in-first-out and vehicles can only move forwards if the cell in front of them is empty.

Lanes have a moving direction represented by the MapDirection enumeration, which consists of values NORTH, SOUTH, EAST, and WEST. We set this explicitly because if a lane has a length of 1, its start and end locations are the same, therefore making it impossible to determine which way traffic flows. When adding lanes to a road, the lanes travelling north must be added before the ones travelling south and the lanes travelling east must be added before the ones travelling west to maintain the left-hand style of driving.

6.3 Evaluation

We believe are roads are well implemented. They fulfill their task of holding a number of lanes without any excess overhead. However, a few possible improvements could be possible, such defining a better way of keeping track which lanes are moving in what direction. In other words, lane orientation in the map is defined only by the order in which lanes are added to the road. So if the requirement is to have left-hand side driving, then the north-moving lane must be added before the south-moving lane. Removing this kind of dependency could make it easier adding lanes to roads. Also, our system was only tested with roads with up to two lanes, so including support for more lanes would be possible.

7 Traffic Lights

7.1 Basic Structure

The TrafficLight class implements traffic light functionality for the simulation. Each traffic light has a duration (how long it should last a single colour) and initial state (red or green). It subscribes to the Ticker upon creation. The nextState() method takes the state it is currently in and sets it to the state it should be in next.

7.2 Ticker Interaction

This is where most of the interesting implementation lies. Each traffic light holds an internal time. On each ticker tick, if its internal time is less than the duration, it increments its internal time. If it hits its duration, it changes to the next colour and resets its internal time. To tell the rest of the system of its colour change, it tells the traffic light controller of its new colour state.

7.3 Traffic Light Controller and Traffic Light Decorator

The TrafficLightController class is the link between the model TrafficLight class and the GUI representation. It follows the singleton pattern, and includes global variables like the duration of all traffic lights and whether or not the traffic lights are enabled. It also includes two "database" type objects: a HashMap, with each TrafficLight instance registering to its GUI representation, and an ArrayList that holds all TrafficLight instances.

The "colourChanged(LightColour colour, TrafficLight tl)" method gets called by the TrafficLight "tl" with the new "colour" it is. This method then uses "tl" and uses it as a key to look up its corresponding GUI representation, a TrafficLightDecorator, in the HashTable. TrafficLightDecorators contais a TrafficLight that it is representing and a JavaFX Circle shape. The circle is what changes colour upon request. First the circle is drawn, and when the "setGUIColour(LightColour colour)", the circle changes colour to the new colour.

The TrafficLightController contains helper methods for disabling and enabling all traffic Lights and changing the duration of all traffic lights.

7.4 Evaluation

We believe that using a HashTable to store (TrafficLight, TrafficLightDecorator) pairs in the controller was a good idea because of its $O(1)$ retrieval time. At first, we were unsure of how to have many intances of TrafficLights linked to TrafficLightDecorators. We first considered having many instances of the controller, but that did not make logical sense. Having the HashMap made it easier to look up which circles must change colour at any given time. However, a minor change that could be possible is removing the ArrayList of TrafficLight instances and only using the HashMap keys to get at a list of all traffic lights. This would remove a data redundancy.

8 Intersections

8.1 Basic Structure

An intersection is a special type of component that connects roads together. It connects at least two roads and a maximum of four. To represent the connections, the intersection has four variables, one for each road. Road positioning relative to that intersection instance is specified by the names of the variables. For example, a road that is north of the intersection gets set as the intersection's north road.

An intersection also contains up to four traffic lights. Traffic lights can be determined automatically by the method "setDefaultTrafficLightsForRoads()", which looks at each road that is set to the intersection and sees if there is a lane in that road that is driving towards the intersection. If there is such a lane, then the traffic light is added. To prevent all the traffic lights from starting with the same initial colour, north and south traffic lights start red, and west and east traffic lights start green. If there are no north or south lights, then the east and west traffic lights start at red. For more information about traffic lights, look at Section 7 on page 11.

8.2 Intersection Controller and Decorator

The intersections have a controller to act as a link between their model and view representations. A HashMap is used in the controller to keep a ”database” where each intersection is registered with exactly one instance of an intersection GUI representation.

Each IntersectionDecorator class is associated with a single intersection instance. Each has up to 4 TrafficLightDecorators that live inside it. The Intersection does not have any explicit circles itself; it relies on the circles of each TrafficLightDecorator that is associated with each TrafficLight.

The most important functionality of the Intersection decorator is the drawIntersection method that draws the wrapped Intersection and produces a visual representation with traffic lights embodied in a stack pane:

```
public StackPane drawIntersection() {
   ...
   return stackPane;
}
```

The locations for each traffic light are determined. Then, for each traffic light, if it is not null, its circle representation gets added to the interection GUI representation.

8.3 Evaluation

We believe that our intersections are well designed. At first, we were unsure of how to display up to four traffic lights at once. By embedding TrafficLightDecorators inside the IntersectionDecorator we were able to display all traffic light circles at once. There was an issue that we had to solve which involved only one of the circles changing colour, despite them all being visible and set to the correct initial states. This was solved by including a method in the TrafficLightDecorator class to return the circle to the IntersectionDecorator and have it manage the drawing and adding the actual circle to the view. This may have been a simple issue with JavaFX panes, because it was always the last added traffic light that would change colour. However, this way, there is a controller that manages combining a few traffic lights into one grid cell view.

9 Ticker

The ticker class is how time is kept in the simulation system. It would start at zero and increment at a given time increment, or granularity, such as every one second. Any type of object that wants to do some operation at each time increment must subscribe to this class. The ticker publishes the time to all subscribers at every time increment. Typical subscribers include vehicles and traffic lights, although other objects can subscribe as well.

The Ticker class is located high up in the package hierarchy because of how central its role is. It was one of the tricker parts of the project implementation because we had to decide how to implement the publish-subscribe relationship and have the ticker ticking at a constant rate. The ticker had to once be re-worked because of some complexity that arose. However, the one aspect that remained constant was the importance of having the publish-subscribe relationship.

9.1 First Implementation

9.1.1 Initial Stages

In the first implementation of the Ticker class, important things had to be decided on, such as how to notify all subscribers of time changes and how to handle time ticking on a periodic basis. Because we were starting from scratch, we had nothing to base it on, so the design was one of the more difficult parts of the implementation.

9.1.2 Basic Structure

The Ticker class followed the singleton pattern, so that the number of instances would be capped at one. Any potential subscribers would implement an interface called TickerListener, which contained a method called "onTick(long time)" that needed to be implemented by the subscriber. This would be the method that would execute on every time increment in the ticker.

9.1.3 Ticking Support

The actual underlying ticking relied on two main aspects: a Timer instance and a TimerTask instance (both part of the java.util package). In general, a Timer instance executes a TimerTask instance at the specified interval. The Ticker class had a class embedded in it, called TickerRunnable which extended the TimerTask class. It also followed a singleton pattern for the constructor and it had a "run()" method that would execute when required by the Timer. This is where each subscriber would be notified with the current time in the simulation. To start the Ticker ticking, it had a method called "start()", which initiated the Timer and gave it the task of running the TickerRunnable at the given interval specified by the variable of type long named TICK_INTERVAL. So overall, after every interval, the TickerRunnable would execute its "run()" method, which would tell all subscribers that the time changed, which would execute some operation. For instance, vehicles would move forwards.

9.1.4 Evaluation

The Ticker class performed well with the model elements of the project. In the test cases performed, vehicles would move properly and traffic lights would change colour. However, there were many issues that had to be resolved. Firstly, we did not like the way in which subscribers were notified of time ticks. The Ticker held a list of all its subscribers, which already violates the key property of the publish-subscribe relationship (publishers of events do not know who its subscribers are, nor should they care). Because of this list, on every tick, we would cycle through this list and notify each subscriber one at a time. This was not ideal because some subscribers would hear the tick before others. This made us think of how we could try to notify all subscribers at once.

Secondly, and more importantly, this implementation did not work with JavaFX threads. An exception would be thrown each time a thread other than the JavaFX thread would try to modify any graphical elements. This was first discovered when we tried to test the GUI representation of traffic lights. We would get the following exception:

```
Exception in thread "Timer-1" java.lang.IllegalStateException:
Not on FX application thread; currentThread = Timer-1
```

This was a major cause for concern, because the goal was to have a fully functioning graphical user interface and not simply displaying vehicles in the console! At first, this was solved by a call to the JavaFX application platform, called Platform. It contains a method "runLater(Runnable r)" that takes any sort of runnable task [6]. This did make the animation work from the Ticker thread, but it was not ideal because it simply schedules the task for some "unspecified time in the future". Finally, a minor issue was that the Ticker had an instance, but all methods were static, so it made us think if having an instance was necessary at all. This is when we decided that the Ticker class must be re-worked in some other way, hence our second, and current, implementation.

9.2 Second Implementation (Current)

9.2.1 Initial Stages

Given the issues faced with the first implementation, we needed a Ticker that would work with the JavaFX thread and that would ideally notify all subscribers at the same time of the tick. We decided to research potential ways the Ticker could be implemented.

9.2.2 Getting Help from Libraries

ReactFX This is a library that helps by adding support for "reactive event streams" that works with JavaFX. In short, it processes events that happen in the system, such as clicks [12]. As the first solution, we used a type of event stream called "EventStreams.ticks(...)", which generated a tick after each time the given time interval passes. This worked for small cases and test files using JavaFX, but due to lack of good documentation, we were unsure of how to proceed with this framework to support the whole simulation system. This library claimed to be inspired by RxJava, a more general reactive approach, so we investigated this next.

RxJava Made by ReactiveX and Netflix, this open-source library provides a reactive programming approach for Java [8]. By the word "reactive", it means that there are some objects that react to something else, which means that many reactions can execute in parallel. There are observers (which are subscribers) that listen to some Observable (the publisher). The observable emits some sort of object and the subscribers react to it when they get the message [7]. We decided to use this library as part of our implementation. Although this library can do many other things with event streams, like filtering or debouncing, we are only skimming the surface of its functionality and only using its publish-subscribe facilitation.

RxJavaFX Also made by ReactiveX, this is a library that allows an asynchronous reactive approach to JavaFX-specific events. It is useful for GUI event processing [9]. Although we decided to use this in our Ticker implementation, we are using a very small amount of its functionality. The only aspect of this library that we are using is specifying that the publisher/observable should run on the JavaFX application thread.

9.2.3 Solution

We decided to use a combination of RxJava and RxJavaFX for our Ticker implementation. The thing that does the ticking is defined as an Observable<Long> from the RxJava package, rx. The type parameterization says that the message that this publisher sends is of type Long, so the current time in the system can be sent. Objects that wish to subscribe to the Ticker must extend the Subscriber<Long> class, also from the rx package. This gives the subscriber three methods to implement: onCompleted(), which gets called once the Ticker terminates, onError(Throwable t), which gets called if there is an error with the Ticker, and most importantly, onNext(Long long), which gets called on every tick. Classes like Vehicle and TrafficLight implement this method to define functionality that must be performed on every tick. To subscribe to the observable's messages, each subscriber class is set to call Ticker.subscribe(...) in its constructor with itself as the parameter. This executes the following line for each subscriber:

```
tickerObservable.takeUntil(stop).observeOn(JavaFxScheduler.getInstance()).subscribe(sub);
```

This tells the observable/publisher to subscribe the subscriber "sub" (a vehicle, traffic light, or anything else), to run it on the JavaFX thread, and to make it run until a stop signal is sent to it (it can still unsubscribe sooner than the signal). The resulting behaviour is that when there is a subscriber for the observable, the Ticker starts and the subscribers perform their onNext operations when a tick is sent out.

9.2.4 Evaluation

This approach works very well with the JavaFX thread because of explicitly specifying ".observeOn(JavaFxScheduler.getInstance())", thanks to RxJavaFx. It is simple to add more subscribers and have them perform some operation, thanks to RxJava. There are only a few downsides with this approach. First, the ticker speed must be set before the simulation begins. Once there is a subscriber, the ticker speed cannot change. For this reason, we request the user sets the ticker speed before beginning the simulation. It is possible in theory, but due to time constraints, we left it as-is. This requires calling Ticker.start() once the ticker speed is set to initialize the observable in-charge of ticking. Second, whatever class that wants to subscribe to the ticker must extend the Subscriber<Long> class. Therefore, this would be the only class that the subscriber would be able to extend, as Java does not support multiple inheritance.

10 Vehicles

The simulation system is, after all, about vehicles and how they behave in different maps and conditions. This section will go in-depth into how vehicles move and the different types that are possible.

10.1 The Vehicle Class

Vehicle is abstract class that all vehicles implement; it enapsulates all generic vehicle behaviour. It being abstract allows for scalability because we can add more types of vehicles such as cars and ambulances. There are two types of vehicles: cars and ambulances, and both extend Vehicle.

Vehicles have a lot of attributes that are either global for all types of instances or are specific to an implementation. Attributes that define vehicles are: priority, behaviour, location, and state. Vehicle priority is represented by an integer, with 1 being the lowest. Vehicle behaviour is represented by an enumeration called VehicleBehaviour, with possible values of average, aggressive, or cautious. Coordinate location is determined dynamically by the "getCurrentCoordinate()" method. Finally, state is determined dynamically by calling all relevant vehicle movement methods and assigning it based on the outcome, which is based on the current state of the simulation.

10.1.1 Car

Instances of Cars are the most common in the simulation. This class extends the Vehicle class to gain all vehicle functionality but with some Car specific attributes. Cars represents basic vehicles, with basic vehicle behaviour. Cars are initialized with average behaviour and with the lowest priority of 1.

10.1.2 Ambulance

Instances of ambulances represent a vehicle with high priority. It is initialized with aggressive behaviour and a priority of 5, which is the highest in our system so far.

10.2 Vehicle Movement and Ticker Interaction

All significant vehicle behaviour is because of its interaction with the Ticker. On every tick by the ticker, the vehicle calls the VehicleController to move. The controller finds the corresponding VehicleDecorator, the GUI representation, in a HashMap of (Vehicle, VehicleDecorator) pairs. Then we begin processing the vehicle's request to move in the moveVehicle method.

Vehicles movement can be divided into two main categories: moving in a lane and turning to a new lane. Before any movement happens, we set the previous lane and coordinate of the vehicle to it's current lane and coordinate to keep track of.

10.2.1 Moving in a lane

Each lane is an array of vehicles, so the movement of vehicles is simply changing the vehicle's position in the lane by increasing its index by a number of steps. Vehicles only move forwards when the slot in front of them is empty. Cars possess AVERAGE behaviour so they will move one slot at a time. On the other hand, vehicles with AGGRESSIVE behaviour such as ambulances, move two steps each time if possible, otherwise they move one step. To move it, we set the current cell in the lane to null, so other vehicles can move to this cell. We increase the vehicle's index in the lane by the number of steps it moved.

10.2.2 Turning to a new lane

After controlling the vehicle movement in a lane, we went to manage the movement of vehicles to other lanes. Vehicles can turn to a new lane only through intersections, which means it has to be at in the end of its current lane. To move to a new lane, there are three main things to consider: reading traffic lights, choosing the next lane to move to, and the ability to turn.

Reading traffic lights In our system, each road has two lanes, and each intersection can connect up to four Roads, which means each intersection can have up to four traffic lights. The readTrafficLight() method in the Vehicle class makes vehicles read only their corresponding traffic light. Reading the correct traffic light depends on the map direction of their lane. For example, if the map direction of a lane is south, and the vehicle is at the end of its lane, that means this vehicle is in the north road for of an intersection, so it has to read the north traffic light. If the traffic light is red, vehicle state is set to 0, which means the vehicle stops, and if it is green, vehicle state sets to 1, which means the vehicle can move. Vehicles with higher priority such as ambulances always can move even if the traffic light is red. After making vehicles listen to traffic lights, they can now choose a lane to go to.

Choosing the next lane to move to Vehicles can only turn when they are at the end of the current lane. Vehicles reads the intersection in front if it and then read all roads connected to that intersection. From these roads, we take only go to lanes with a legal map direction for a given vehicle. For example, assume vehicle A is in a west road and its driving direction is East, and this vehicle want to move to the south road. For the south road, there are two lanes, one with north moving direction and the other with south moving direction. So, vehicle A can only choose lane which map direction is south. "getLaneOptions()" checks all connected lanes of an intersection and tests the validity of lanes in terms of the map direction and state. If the map direction is legal for a vehicle and the lane state is 1 (lane is enabled), this method puts the lane into the list. The "chooseLane()" method takes the array list of all valid lanes and chooses a random lane for the vehicle.

The Ability to Turn To avoid vehicle crashes in intersections when they turn, because they chose the same lane to go to, we have to regulate the vehicle movement in intersections. The first idea was to use vehicle IDs. Since each vehicle has a unique ID, we can compare them, so vehicles with higher IDs move, and others wait. After generating large numbers of vehicles on a map, we decided comparing IDs was not a good choice. If a vehicle at the front of a queue has an ID of 3, all vehicles behind that vehicle also have to wait for vehicles in the other lanes to pass. This made us give vehicles priorities to turn. We then had the idea giving vehicles at intersections a "vehiclePriorityToTurn" value, a random number from one to four, one for each possible vehicle at the intersection. The vehicle with the highest vehiclePriorityToTurn value moves, otherwise it waits.

We first made vehicles decide who will turn amongst themselves. By using priority, we need to give each vehicle a new priority each time they are at an intersection. Each vehicle gives other vehicles in the intersection priorities. Then each vehicle compares against the others. If there are two vehicles at an intersection, and each gives priority to the other, they both will try to move, so the problem still remains.

However, what we did next is implement "giveVehiclePriorities(ArrayList¡Integer¿ randomPriority)" in the Intersection class, which makes random vehicle priorities generate at intersections, not vehicles. Therefore, the Intersection became a subscriber of the Ticker, so it can decide on each tick who will turn next. The "vehicleTurnFirst(ArrayList¡Vehicle¿ vehicles)" method in the Intersection class takes the array list of vehicles with priorities at the intersection as a parameter, compares the vehiclePriorityToTurn only for vehicles where their traffic light state is GREEN, then sets the vehiclePriorityToTurn to 1 for the vehicle with the highest vehiclePriorityToTurn, or vehicles with vehiclePriority equal to 5 such as ambulances, otherwise sets to 0.

The final step to make vehicles turn is in "int vehicleTurn(Lane l)" method in Vehicle class. This method checks four things:

1. If a vehicle is at the end of its lane.
2. If the chosen lane is not null.
3. If the first cell in the chosen lane is empty.

4. If vehiclePriorityToTurn equals to 1.

If these conditions are obtained, the vehicle turns, otherwise it stops.

All movement methods, such as turning or moving straight, return an integer called "move". It is like a boolean, except with more information about the result. If move gets set to zero, that means the vehicle did not move and therefore we should not animate the vehicle movement. If move is greater than one, then the vehicle can be animated to move. If move was set to three, that means the vehicle should be removed from the simulation. All the movement methods may or may not actually move the vehicle in the model. When we go to do the vehicle animation, this is where the previous lane and coordinate come in. We must now animate the vehicle from its previous lane and coordinates, not its new ones, otherwise the vehicle would be moved twice.

10.3 Evaluation

Making the Vehicle class an abstract class was a good idea because this makes our system extensible to new types of vehicles in the future. Fixing the vehicle movement bugs, namely when two vehicles would drive into the same lane at the same time, was a large accomplishment due to its real-time complexity. In terms of general vehicle movement, an area for improvement could be the steps taken to move. Maybe there is a better way of doing the animation, instead of setting the previous lane and coordinates and doing the animation based on that.

Vehicles also do not know if there is an ambulance behind them. In future work, we would vehicles cleverer in their movement, so if there is an ambulance behind them they should have the higher vehiclePriorityToTurn, so ambulance can move faster. Even though vehicles no longer crash, it would be better if more than one vehicle can move through an intersection at a time.

Vehicles can never go in the wrong lane in our system. However, making U-turn is not allowed yet in the system if they reach an intersection with no lane options.

Overall, we believe that the Vehicle class performs very well regarding the different states a vehicle can hold and the different movement results that can be returned. Therefore, vehicles are robust to any kind of map or driving conditions.

11 Log

The simulation system writes a log file with the corresponding timestamp each time the simulation starts. The log file name is with the form "Log_Year-Month-Day-Hour-Minute-Second" and it gets stored in the "logs" directory in the working directory, i.e. where the source code is or where the executable is placed. Each object that is subscribed to the ticker is appended to the log with all its attributes. We are able to trace on each tick the activity generated by the object and it is useful for debugging processes, audits, and statistics.

To achieve the logging functionality we use the java.util.logging.Logger and we also extend the log class to the subscriber so it can interact easily with the Ticker to write the state of every subscriber on each tick.

12 Testing the System

Before we had our GUI screens, we tested the logic of our system using JUnit testing. In the src directory, we have a ”test” package. This is where all of our test files went. We used JUnit tags such as @assertEquals(...), @assertNotNull(...), @Before(), and more. This allowed us to see whether the outputs we were expecting were achieved.

However, tests involving the Ticker were done using main() methods, because we found that JUnit did not support multiple threads in its text environment. We researched into this some more, but found it easiest to use the main() methods in our test cases for our testing purposes. Additionally, once we had some GUI screens, we relied less on JUnit testing and more on integration testing using those screens.

Part V
The Application

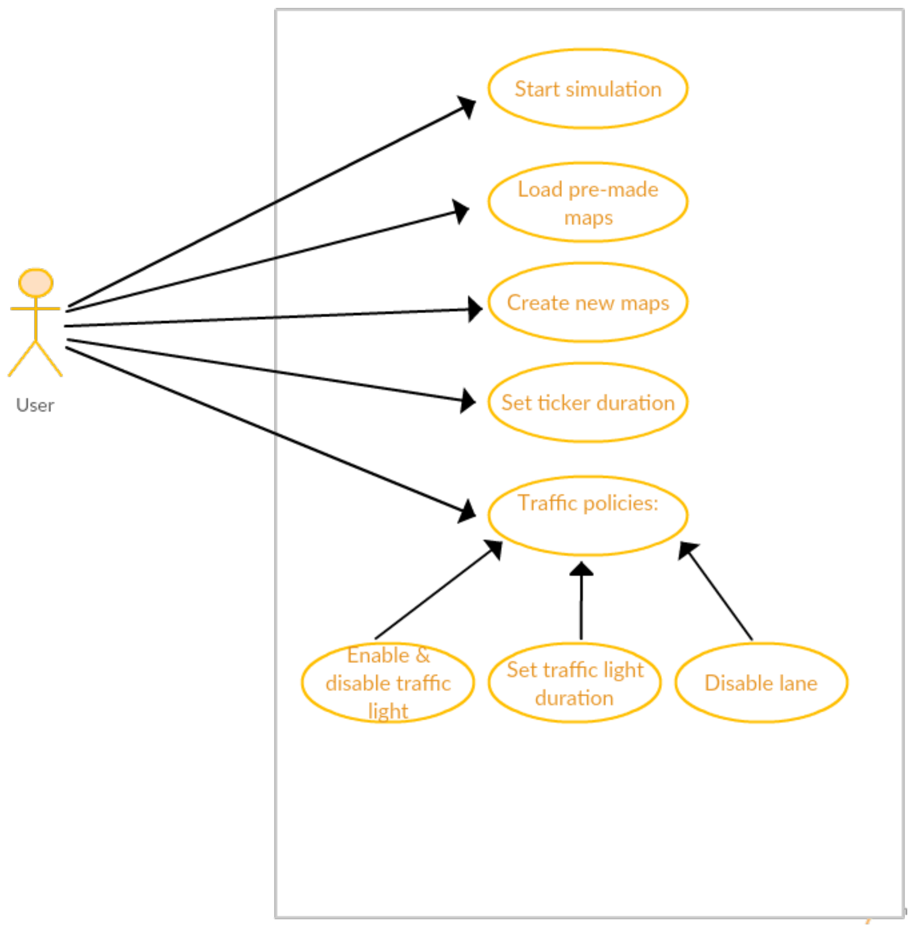
13 Start-Up

When the user starts the system, they get presented with a start screen. After pressing the start button, the user gets presented with a choice of modes: opening a map or creating a new map. The screens are loaded using a series of controllers. A singleton instance of the StartUpController is made, which controls the first few screens.

Opening a map opens a File dialog where the user can open a pre-made map file. The simulation comes with some map files pre-built for the user. This then brings the user to the simulation screen. The StartUpController hands control to the SimulationController, which handles drawing the SimulationScreen.

Choosing to make a map brings the user to the Map Maker screen. They choose a width and height of a map, place components on it, and save it as a new map. The user can then run the simulation on it. The StartUpController hands control to the MapMakerController, which handles drawing the MapMakerScreen.

This is a use-case diagram that describes the steps the user can take in our system:



14 Simulation Screen

Aimed at making a user-oriented simulation system, we have a main simulation screen where users can both monitor the simulation process and control the simulation system by using various controls. Users would load maps from file to run the simulation on.

14.1 Loading Maps

When loading a map from file, we first had an issue where the traffic lights appeared, but never changed colour. This was fixed by making the traffic lights re-register with the Ticker and the TrafficLightController. Intersections also re-register with the Ticker.

14.2 JavaFX Scene Builder

JavaFX Scene Builder is a visual layout tool that lets users to quickly design JavaFX application user interfaces by dragging and dropping UI component to a work area, modifying their properties and applying style sheets. The FXML code which is automatically generated can be combined with Java projects by binding the UI to the application's logic to handle the events and actions taken on each element. At first, we chose JavaFX Scene Builder as our main GUI development tool.

Problems arose after we finished building FXML files and tried to connect the UI interface with simulation models. We found only one controller can be used in a FXML file which means we need to figure out how to communicate between different controllers. This problem first arose when we loaded pre-made maps into the simulation.

Users need to choose a pre-made map before going into simulation screen, this needed an intermediate controller to deliver map name between two interfaces. There will be lots of this kind of communication so many intermediate controllers need to be added which could increase complexity. Thinking about this, we finally gave up JavaFX Scene Builder, decided to use pure JavaFX.

14.3 Simulation Screen

The simulation screen was built using Model-View-Controller (MVC) architecture pattern. SimulationController.java is the controller to draw the screen and generate the log for the simulation. SimulationScreen.java is the corresponding view used to manage UI components of the interface. The model is read from the Map components that are loaded.

We used the built-in layout container classes, called panes that are available with the JavaFX SDK to manage UI components of simulation screen. The JavaFX SDK provides several layout panes for the easy setup and management of classic layouts such as rows, columns, stacks, titles, and others. We used the BorderPane layout pane for the simulation screen. The BorderPane layout pane provides five regions in which to place nodes: top, bottom, left, right and center.

To keep the interface simple, only three parts were used in our simulation screen: top, center and right. Title of the simulation screen "LondonSW Simulation System" was set on the top of the BorderPane. We used the center part to load the chosen pre-made map in which simulation process will happen. The right part was mainly used to monitor and control the simulation process. Here we used the VBox layout pane to make sure nodes are arranged in a single column.

Labels including "Number of Cars", "Ticker interval", "Traffic Light Duration", "Time Ticked", "Vehicle Time Spent Standing" were set for simulation monitor to help users have a better understand about how is the simulation process going.

"Start" and "Reset" buttons are used to control whether to start or stop the simulation process. Users can click "Add Ambulance" to add an ambulance whose behavior is aggressive and can also delete it. There is a "Set Traffic Light duration" button. Once it is clicked, there will be a dialog allows users to set traffic interval(100-1000 millisecond) by a spinner. "Disable Traffic Light" is used to delete all traffic lights of the map and "Enable Traffic Light" to restore all traffic lights to the map. This is to simulate situation in which traffic lights cannot work properly.

We used a slider to control number of cars in the system. Users can set number of cars they want as long as it is in the available range. The minimum car number is 1, the maximum number is set automatically depends on the overall number of slots of all lanes in the map ($MaxCarNumber = 0.6 * SlotsNumber$). This means the simulation process won't crash due to too many cars results in no slot is available and to make sure the traffic can be coordinated properly.

Generating cars is captured by the newValue the slider is set to. If oldValue is smaller than newValue, new cars ($newValue - oldVlue$) would be generated to the map. Car generation happens with the "generateCar(...)" method. We get a random lane from the map, get an empty slot in that lane, and generate the vehicle there. Otherwise, system would delete ($oldValue - newValue$) cars randomly from the vehicle list. The vehicle gets deleted by calling the VehicleController method "removeVehicle(int i)". It removes a vehicle from the list of all vehicles at index i. The vehicle unsubscribes from the ticker, deletes itself from all databases, then gets set to null. Java garbage collection will then remove that instance completely.

14.4 Map Graphics

The whole Map grid layout consists on a GridPane which is a flexible grid of rows and columns that holds in each row and column a specific pane. Each cell is a StackPane, which can either be grass (empty square), a Road, or an Intersection. All drawings are of our own authorship because we have used the tool GIMP, an open source graphic editor [11]. The size of each stack pane is dynamic and we are able to change it by changing a resize factor, which is an important attribute used in many of our drawings.

14.5 Decorators

Our implementation is using the Decorator Pattern to extend the functionalities of each component so that the objects can be drawn by wrapping the original object and invoking a draw method for each component. There are 5 main wrappers MapGridGUIDecorator, IntersectionDecorator, RoadGUIDecorator, TrafficLightDecorator and VehicleGUIDecorator.

14.5.1 MapGridGUIDecorator

This is the class that manages the drawing of the entire map. By traversing the MapGrid representing the Map, we check what type of component is in each cell. We call the corresponding decorator class for that type of component.

14.5.2 RoadGUIDecorator

The Road is a stack pane that has a rough grey background and the arrows of the lane representing which way traffic flows are drawn programatically in each square.

14.5.3 IntersectionDecorator

The intersection is drawn with the same background as a Road but in addition it has a yellow diagonal cross. For information about drawing intersections, please refer to section 8 on page 12.

14.5.4 TrafficLightDecorator

The traffic lights are also drawn programatically using its decorator class. For information about drawing traffic lights, please refer to section 7 on page 11.

14.5.5 VehicleGUIDecorator

Vehicle movement is displayed by using the VehicleGUIDecorator class. Each vehicle will have exactly one VehicleGUIDecorator associated with it. We have defined different states of the vehicle so we can track their movements and make them move properly:

- State 0 is when a vehicle is not moving
- State 1 means that the vehicle is moving straight.
- State 2 means that the vehicle has entered an intersection
- State 3 is a state where the vehicle has been deleted or has exited the simulation.

14.6 Evolution of Vehicle Drawing and Animation

Our vehicle movement evolved over the course of the project, with many improvements made along the way.

14.6.1 First Implementation

After the map's grid was able to be drawn dynamically, the vehicle now had to move on top of the lanes. It was challenging at first because the obvious way of having the vehicle move between grid cells is not possible. The first step towards our solution was having a rectangle representing the vehicle fill the whole grid cell, regardless of whether it is moving vertically or horizontally. The location of where the rectangle should go was determined by a formula, which took its original placement in the map. The coordinate x- and y-positions of the vehicle are multiplied by the image dimension and the resize factor. The actual movement of the vehicle is dependent on the map direction it is coming from and the map direction it is going to. So if a vehicle is moving east, then north, that means it is turning left and a left turn animation is required. A JavaFX TranslateTransition is used to move the vehicle.

However, turning the vehicle was quite complex. In the first implementation, a vehicle would simply shift into its new location, so a different edge of the vehicle would now be moving forwards. That did not lend itself to a realistic simulation. Additionaly, because of the different kinds of cases of movement, like east to north, west to south, et cetera, we had a lot of duplicated code with only a few values changed in each case. Furthermore, the nature of the animation was shifting it by some x and y values relative to where the vehicle currently is. This made the animation imprecise and over time, vehicles would shift out of their lanes and start moving on grass or on top of other lanes. As a consequence, this kind of animation only worked with a ticker speed of 1000ms. If the ticker was made faster, the animation would become more imprecise, with vehicles not reaching the cells they should have in time. This approach worked well in a very limited amount of cases and needed to be reworked to work with a variety of ticker speeds and many vehicles. This brought us to our second implementation of vehicle movement.

14.6.2 Second Implementation (Current)

Because of all the issues with the first vehicle movement, namely vehicles shifting out of place and not working with various ticker speeds, we re-worked the animation to a much simpler process. The process is:

1. Get the current coordinate location of the vehicle
2. Calculate the new coordinate location for the vehicle
3. Calculate the required vehicle rotation based on where it is moving from and to
4. Determine the actual pixel locations for the new location
5. Set the movement translation to an exact location
6. Move and rotate the vehicle

There are helper methods to calculate some of the steps. The method "directionToTranslation(MapDirection d)" takes a MapDirection and translates it into a coordinate representing a movement in that direction. For example, passing in a parameter of EAST returns a Coordinate with the value of (1,0). The method "getRotationFromDirectionChange(...)" takes the direction the vehicle is moving from and to as parameters and returns the angle which the vehicle must turn by. Most importantly, the method "coordinateToPixels(Coordinate c, MapDirection d)" takes a location in the map and a direction as parameters and returns the exact location to where the vehicle must move to. It is also used to determine the initial location of the vehicle. The MapDirection parameter makes sure that the vehicle gets drawn in the correct lane.

There are many advantages to this second implementation. First, there was a drastic reduction in code duplication. The process was converted to a set of simple steps which works in any situation. In addition, because of each coordinate having a distinct location, the vehicle knows exactly where go. This makes it work flawlessly with any ticker speed. Finally, the vehicle does not shift out of its lanes over time.

14.7 Simulation Statistics

We have a couple of traffic management policies. These are:

- Changing the duration of traffic lights
- Disabling or enabling traffic lights
- Increasing or decreasing the number of vehicles

By doing these three things, the effect of them can be seen in the ”Vehicle Time Spent Standing” statistic. This is a percentage that gets calculated using all the vehicles in the map. Each vehicle has two variables associated with it for the calculation of this statistic: timeSpentStanding and timesTicked. Each time the vehicle was unable to move, its timeSpentStanding increases. A vehicle is unable to move if it is at a red light or if there was a vehicle in the slot in front of it. The increment happens in the VehicleController class when the ”move” result is zero, i.e., it could not move forwards.

```
if(move == 0) {
   Vehicle thisVehicle = vehicleGUIDecorator.getVehicle();
   thisVehicle.incrementTimeSpentStanding();
}
```

For the percentage calculation, there is a local subscriber to the ticker in the SimulationScreen class. It is used for doing any operation when the ticker ticks, like increasing the ”Times Ticked” label and calculating this statistic. Each time the ticker ticks, the method ”getPercentageStanding()” is called and the output is set to the label.

In this method, the VehicleController gets queried for two values: the total time spent standing for all vehicles and the total times ticked for all vehicles. Each method gives the sum of all timeSpentStanding and timesTicked, respectively.

```
int timeSpentStanding = VehicleController.getTotalTimeSpentStanding();
int totalTimesTicked = VehicleController.getTotalTimesTicked();
```

To get the average time spent standing statistic, the following calculation is made:

```
double ans = (double) timeSpentStanding / totalTimesTicked * 100;
return Math.round(ans * 100.0) / 100.0;
```

This statistic can tell us about the amount of congestion on the roads and how external factors like traffic lights can affect vehicle movement over time.

14.7.1 Interesting Trends

Many interesting trends to this statistic can be observed by manipulating the three controls available:

- The more vehicles there are, the higher the percentage of vehicle time spent standing is.
- When holding the simulation conditions stable (e.g. keeping a constant number of vehicles, not changing traffic light duration), the percentage of vehicle time spent standing stabilizes over time and does not differ by about one percentage.
- Increasing the duration of traffic lights increases the percentage of vehicles standing, and decreasing the duration of traffic lights decreases the percentage of vehicle time spent standing.
- Disabling traffic lights does not completely bring the percentage of vehicle time spent standing to zero. This is because there may still be other vehicles getting in the way.
- Setting the number of vehicles to zero resets the statistic because every car in the simulation is new.
- Adding one more vehicle to the simulation does not affect the statistic significantly.

15 Map Maker Mode

15.1 Map Making Basics

To make our system more flexible to different kinds of maps, we allow the user to build their own maps to run the simulation on if they do not like any of the pre-made maps. When starting the system, if the user chooses to "Make a new Map", they are prompted to choose a width and height. To prevent maps that are too small or large to view, the width and height are limited to the range of 5 to 30. An empty map of the width and height that they chose is generated. The user can then proceed to put map components into the grid by clicking on the desired component and clicking to where on the map they want the component to be. Map components include: intersections, roads that run vertically (North-South), roads that run horizontally (East-West), and grass (an empty/null, square). Roads are always added with a lane going in each direction. If a component was placed in a square by accident, the "grass" component can be added to empty that square. When the user finishes, they can press the "Save Map" button to save the map to disk. If the user does not like their map, the "Reset Map" button removes all components from the map. If they decide to not build a map anymore, the "Go Back" button brings them back to the mode selection screen.

15.2 Implementation

The Empty Map The empty map is represented by the Map class, which contains the MapGrid of no components. To allow clicking on the map, we traverse through the map, visiting each cell, and adding an on-click listener to each cell. Since the Map is represented by a JavaFX GridPane, getting the node to add the on-click listener to at the specified location was not trivial. We included a function called "getNodeFromIndex" that takes the x- and y-coordinates and the GridPane as parameters. It gets the node by looking throught all the children of each GridPane cell, and if that Node's location equals the location that we requested, that Node from the GridPane is returned. Now we know when the user clicks on the map to place a map component.

Placement of Map Components When the user selects a component from the right of the screen and clicks on a location in the map, an instance of that component is actually created in the map. For instance, when placing an intersection in the map, an Intersection object gets created and placed in that space. It is set with no roads attached and no traffic lights. When placing a bit of road, either North-South or East-West, an instance of the Road class is created every time. The Road instance's start and end coordinate locations are the same, so a road of length 1 is created. Two lanes are added, with each going in opposite directions.

Keeping Focus At first, building maps was a very annoying task. The user would have to click on the map component on the right, then click on the empty grid square, then go back to click on the map component again, followed by an empty grid square, and so on. This was solved by tracking of what on the screen gets focus and what held the focus previously. Focus means what was last clicked or selected by the user, that is, the mouse cursor was "focused" on a specific element on the screen. The focus is represented by a Java enum, with entries like ROADNS (for a road that travels vertically) and INTERSECTION.

When this mode starts up, the current focus is set to nothing, and the previous is null. The values are stored in the MapMakerController. As an example, if the user first clicks on the Intersection component image, that image gains focus. A blue glow surrounds the image to represent focus. If the user then clicks on an empty map grid square, that map grid square gains focus and the previous focused gets set to Intersection. The map grid checks was was previously focused. It will see that Intersection was previously focused, and place the component in the clicked map grid square. However, to make it easier on the user, focus is then placed back on the Intersection component image so they can keep clicking intersections into the map. The same applies for all other component images.

Saving the Map When the user decides to save the map, they first get prompted for a file name. The file name cannot be empty, and this is enforced by disabling the "OK" button in the Save dialog while the textfield is empty. When the user hits the "OK" button, the saving process begins. Because of the way the map components were placed into the map, all the roads are separate and disconnected and all intersections are not connected to any roads. In other words, if there is a road of length 5 moving vertically, there are actually 5 separate roads moving vertically. We need to ”glue” together all the bits of roads, connect those roads to the relevant intersections, and add all traffic lights.

The method in the MapMakerScreen class called ”buildAndSaveMap(Map m)” takes the map ”m” that the user built. Using that map’s width and height, a new empty map is created that will serve as the ”glued together” and final verison of the user built map. We traverse the broken map, and when we discover a component, we process it. Discovering an intersection is the simplest case. We remove the intersection from the old map and place a new intersection into the old map at the same location. For bits of Road instances, it is trickier. If we discover a bit of road that is moving horizontally (east-west), we then have a while loop moving down the map row to see how long the road is. This way we determine the start location of this road (the original found piece) and the end location of this road (the last bit of road that was not null). We create a new road, add 2 lanes, remove all the bits of road from the old map (so they do not get added to the fixed map twice), and add the new road to the new map. A similar process is done for roads moving vertically. Each time a new stretch of road bits is discovered in the old map, this process is followed to ”glue” all road sections together.

Now that we added all Roads and Intersections to the new map, we must connect the ”edges” and ”nodes” of our map, i.e. our roads and intersections. The method ”assign-RoadsToIntersections(Map m)” takes the fixed map that we just built as a parameter. We retrieve the list of all intersections from the map and determine the surrounding coordinates for that intersection. If there is a road component in any of the coordinates, the intersection gets assigned that road. For example, if there is a Road component north of the intersection, that road gets assigned as the north road of that intersection. This is done for all intersections. Now that all roads are glued and all intersections have been assigned roads, the map can now finally be saved to disk using serialization.

Map Validation and Robustness When saving the map, there is no map validation. We do not check whether all roads connect to some intersection and that no intersections are floating alone with no roads. Therefore, the user is able to build any meaningless map. However, this is fine. The simulation is robust against these kinds of map designs by having the vehicles behave in appropriate ways. For instance, if there is a road without an intersection at the end of it, the vehicle simply leaves the simulation. If there is a road connected to an intersection, but no other roads to go to, the vehicle simply stays in place once it reaches the intersection because it has nowhere else to go. So overall, no matter how poorly built the map is, the vehicles will act accordingly and there will be no system crashes.

15.3 Evaluation

Although the map building process was optimized by keeping focus and quick map component placement, there are a few areas where the process could have been improved. Some sort of click-and-drag functionality would make it easier to place a lot of components in big maps. Some of the non-GUI functionality helper methods could have been moved to the controller to keep GUI and logical methods separate. When saving the map, we should have probably checked if each newly discovered adjacent road is moving in the same direction as the first piece of discovered road. Some map validation would be nice to have, regardless of how robust the system is. Finally, a dialog saying where the map was saved to would be useful so the user would know exactly where to look when trying to load their map for the simulation screen.

Part VI
Teamwork

16 Communication

We use WhatsApp for general communication, like coordinating meeting times. We use Slack for project discussion, like discussing new ideas/problems and sharing documents. We have general discussion for all group members and private communication between two members to talk about issues like program interfaces without bothering others.

17 Group meetings

We have scheduled group meetings twice a week, mostly on Monday and Friday. We discussed task progress and assigned new tasks normally on Monday. On Friday, there would be a long-duration meeting. we would talk about the project in detail and members would code together.

18 Agile development with Mingle

Because of the nature of the project, continuous learning and adaptation to the emergent state of the project are unavoidable. We use Mingle for project management which is based on Agile software development principles. It is designed to integrate with a team's workflow. We used Mingle's Planner feature to define objectives for each team member, track a plan's progress, and receive alerts when a plan changes. Mingle helps our team communicate intentions, collaborate easily, and effectively solve problems by having more efficient conversations with team members.

At the task level, Mingle allows us to assign teammates to a specific action, so everyone can see who is working on what. At the end of our group meetings, we will assign tasks to group members by adding a new story at Mingle planner including a specific task description, an estimate duration, status (new, in progress, complete), a task priority (must, should could), the owner of the task.

At the project level, we use Mingle to start a conversation if an upcoming deadline has not been met. We often talked about a task's status to have a better grasp about how is the progress going.

At the program level, Mingle sends us alerts so that everyone can follow up. We also exported the task file and uploaded to Github to make it available and more convenient for everyone to check their tasks at any time.

18.1 Github

IntelliJ is our main platform for coding. We use Github as our main source-code repository. We have a master branch and four personal branches. Everyone is free to experiment and commit changes. Anything in the master branch is always deployable. Branches aren't merged until the change was reviewed. Once we have done our tasks, we commit and add an associated commit message, which is a description explaining why a particular change was made. The master branch would close a merge request and sometimes roll back changes if a bug was found, since each commit is considered a separate unit of change. Our Slack chat was configured to include a GitHub bot to tell us when changes were made. Our team became very proficient at Git over the course of development.

Part VII
General Project Evaluation

19 Things that went well

We had clear goals for each development stage, i.e. what must/should/could be achieved for each iteration. Before and after each iteration, we would check and make sure everything has been achieved. This ensures our entire development process is progressing well. By following Agile development principles, our team did a good job responding to unpredictability through incremental and iterative work.

From the perspective of software development, we adhered to the MVC architecture. We have clear hierarchical model structures, e.g., a map contains roads and intersections, traffic light and lane are owned by intersection and road respectively.

We made the system a user-friendly application. Users can monitor and control the simulation process by going into simulation mode. The map maker mode allows users to design maps with any dimensions or map components. A simulation log is available after each simulation for users to analyze the whole simulation process.

In general, we worked well as a team, with each member focusing on a roughly different aspect of the system. There were no major conflicts and everyone understood the importance of good, hard work for this project.

20 Things that did not go well and what we did

We had many difficulties along the way, but we always managed to pull through and resolve them. The ticker went through several iterations itself, with improvements being made each time. The animation started off basic, which also got improved several times over the course of the project. Bugs like traffic lights not working in loaded maps got fixed promptly. And finally, the resize factor used to display maps poorly, but now does a good job for all map sizes.

21 Possibilities for the future

It is impossible to implement all ideas we had because of short term. In the future, we can add more vehicle types like police cars, bicycles, buses, etc. as well as more road types including railroads and overpasses. There can be arc intersections instead of cross intersections. We can make our system adapt to real maps like Google Maps. By providing a real location, users can get traffic situations through our system. By connecting background log files to real maps, it would be possible to deliver these log files to real traffic monitoring stations for furthter-step traffic analysis.

Part VIII
Peer Assessment

We have decided to distribute the points as follows:

Name	Points
Violetta	20.0
Santiago	20.0
Rawan	20.0
Yakubu	20.0
Jia	20.0
Total	100.0

We distributed the points evenly because we believe that each member contributed a lot to the project. Each person has something that they implemented and was their idea, and many hours were spent by all on this project.

References

[1] Macroscopic traffic flow model. `https://en.wikipedia.org/wiki/Macroscopic_traffic_flow_model`, February 2015. Accessed: 28 March 2016.

[2] Bazghandi Ali. Techniques, advantages and problems of agent based modeling for traffic simulation. *International Journal of Computer Science*, 9(1):115–119, January 2012.

[3] P. A. M. Ehlert and L. J. M. Rothkrantz. Microscopic traffic simulation with reactive driving agents. In *Intelligent Transportation Systems, 2001. Proceedings. 2001 IEEE*, pages 860–865, 2001.

[4] Serge P. Hoogendoorn and Piet H.L. Bovy. State-of-the-art of vehicular traffic flow modelling. *Journal of Systems and Control Engineering.*

[5] Andrew Lansdowne. Traffic simulation using agent-based modelling. Master's thesis, University of the West of England, 2006.

[6] Oracle. Platform. `https://docs.oracle.com/javase/8/javafx/api/javafx/application/Platform.html`, 2015. Accessed: 29 March 2016.

[7] ReactiveX. Observable. `http://reactivex.io/documentation/observable.html`. Accessed: 28 March 2016.

[8] ReactiveX. "rxjava". `https://github.com/ReactiveX/RxJava`, March 2016. Accessed: 28 March 2016.

[9] ReactiveX. "rxjavafx". `https://github.com/ReactiveX/RxJavaFX`, March 2016. Accessed: 28 March 2016.

[10] T. Schulze and T. Fliess. Urban traffic simulation with psycho-physical vehicle-following models. In *Simulation Conference, 1997., Proceedings of the 1997 Winter*, pages 1222–1229, Dec 1997.

[11] The GIMP Team. About gimp. `https://www.gimp.org/about/`, 2015. Accessed: 30 March 2016.

[12] TomasMikula. "reactfx". `https://github.com/TomasMikula/ReactFX`, January 2016. Accessed: 28 March 2016.

[13] Femke van Wageningen-Kessels, Hans van Lint, Kees Vuik, and Serge Hoogendoorn. Genealogy of traffic flow models. *Euro J Transp Logist*, February 2014.

Part IX
Appendix

A Git Log

Author	Date	Message
violetavk	2016-01-22	Initial commit
Violet	2016-02-08	initial structure created
Violet	2016-02-08	added some more classes for importing maps (from OpenStreetMap)
Violet	2016-02-08	Moved project files and added .gitignore
Violet	2016-02-08	First report draft
Violet	2016-02-08	Second draft
Violet	2016-02-08	Merging in ‘reports’
Violet	2016-02-08	Third draft of initial report
Violet	2016-02-09	Final version of initial report
Violet	2016-02-10	Adding comments for all the classes we have so far as to what they should do
yakubu	2016-02-10	added coordinate class
rawanmoh	2016-02-10	updates car class
Jia	2016-02-10	This is the Class of Intersection
jia0627	2016-02-10	This is the Class of Intersection
jia0627	2016-02-10	AnimationTimer
santiago	2016-02-11	Demo Version
santiago	2016-02-11	Merge remote-tracking branch ‘origin/master’
rawanmoh	2016-02-11	update car class
rawanmoh	2016-02-11	update car class
rawanmoh	2016-02-11	update car class
violetavk	2016-02-11	added some code to Lane and Road; added equals method to Coordinate; added JUnit test for Lane
rawanmoh	2016-02-12	update car class
Violet	2016-02-12	Forgot to add libraries for junit tests yesterday; added potential controller for View; added another method to Lane; started RoadTest class
felix	2016-02-12	Added test for coordinates and changed exception in lane
felix	2016-02-12	Updates to intersection
rawanmoh	2016-02-12	update car class

rawanmoh	2016-02-12	Merge remote-tracking branch 'origin/master'
rawanmoh	2016-02-12	update car class
Violet	2016-02-12	Adding CarDirection, MapDirection, LaneTest update
rawanmoh	2016-02-12	update car class
yakubu	2016-02-12	Traffic Lights
Violet	2016-02-12	Updates to Lane
yakubu	2016-02-12	LaneTest
yakubu	2016-02-12	Merge remote-tracking branch 'origin/master'
Violet	2016-02-12	adding trafficlighttest
yakubu	2016-02-12	LaneTest
yakubu	2016-02-12	changing git ignore
yakubu	2016-02-12	Merge remote-tracking branch 'origin/master'
yakubu	2016-02-12	Traffic light test
santiago.anda@outlook.com	2016-02-13	Change variable names
santiago.anda@outlook.com	2016-02-13	Change variable names
felix	2016-02-13	Map and TickerInterval changes
jia	2016-02-15	Intersection validation check
Violet	2016-02-15	Updates to Lane arguments and MapDirection
Violet	2016-02-16	Adding some basic GUI screens
rawanmoh	2016-02-16	Add choose vehicle direction randomly
rawanmoh	2016-02-16	Merge remote-tracking branch 'origin/master'
4ND4	2016-02-16	Update README.md
violetavk	2016-02-16	Merge pull request #1 from 4ND4/master
rawanmoh	2016-02-17	create vehicle Test modify Vehicle class
Violet	2016-02-17	Updates to Road class
Violet	2016-02-17	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet	2016-02-17	uncommented Alert dialog in StartUpController
rawanmoh	2016-02-17	Merge remote-tracking branch 'origin/master'
Violet	2016-02-17	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
yakubu	2016-02-17	test
jia	2016-02-17	intersection test
rawanmoh	2016-02-17	pull reauest test

violetavk	2016-02-17	Merge pull request #4 from mugu101/master
violetavk	2016-02-17	Merge pull request #3 from RawanMoh/master
violetavk	2016-02-17	Merge pull request #2 from Jia0627/master
Violet	2016-02-17	Adding Ticker class functionality
Violet	2016-02-17	Adding Map and Simulation updates
Violet	2016-02-17	Updating readme a little
Violet	2016-02-17	Adding a grid system to our map
Violet	2016-02-17	forgot to add grid integration
Violet	2016-02-17	test file into view
yakubu	2016-02-17	traffic light states
violetavk	2016-02-17	Merge pull request #5 from mugu101/master
jia0627	2016-02-17	progress report
jia0627	2016-02-17	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
violetavk	2016-02-17	Merge pull request #6 from Jia0627/master
jia	2016-02-17	Intersection validation check when setting a new road getRoadOptions
violetavk	2016-02-17	Merge pull request #7 from Jia0627/master
Violet	2016-02-18	Changes to MapGrid, Map, and Road
rawanmoh	2016-02-18	remove: vehicleLifTime vehicleDirection and their methods
rawanmoh	2016-02-18	remove: vehicleLifTime vehicleDirection and their methods
rawanmoh	2016-02-18	remove: vehicleLifTime vehicleDirection and their methods
violetavk	2016-02-18	Merge pull request #8 from RawanMoh/master
Violet	2016-02-18	Adding ticker
rawanmoh	2016-02-19	remove some carDirection method
violetavk	2016-02-19	Merge pull request #9 from RawanMoh/master
rawanmoh	2016-02-19	Add vehicle Behavior
jia0627	2016-02-19	intersection validation change
jia0627	2016-02-19	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
violetavk	2016-02-19	Merge pull request #10 from RawanMoh/master

rawanmoh	2016-02-19	//new
rawanmoh	2016-02-19	//new
jia0627	2016-02-19	intersection validation change
jia0627	2016-02-19	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
violetavk	2016-02-19	Merge pull request #11 from Jia0627/master
Violet	2016-02-19	added misc.xml to gitignore
Violet	2016-02-19	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
yakubu	2016-02-19	New traffic Light Class
violetavk	2016-02-19	Merge pull request #12 from mugu101/master
Violet	2016-02-19	update to gitignore
rawanmoh	2016-02-19	Add moveVehicle and its test
rawanmoh	2016-02-19	Add moveVehicle and its test
violetavk	2016-02-19	Merge pull request #13 from RawanMoh/master
felix	2016-02-19	Add class MapTest
violetavk	2016-02-19	Merge pull request #14 from 4ND4/master
felix	2016-02-19	Validation corrections
felix	2016-02-19	Added more tests to Intersection class
violetavk	2016-02-19	Merge pull request #15 from 4ND4/master
Violet	2016-02-19	Integrated Ticker with Traffic light; run TrafficLightTest main method to see how it works
felix	2016-02-20	Update test
4ND4	2016-02-20	Add class MapTest
felix	2016-02-20	Add class MapTest
4ND4	2016-02-20	Add class MapTest
4ND4	2016-02-20	Add class MapTest
4ND4	2016-02-20	Add class MapGridGUI
felix	2016-02-20	Add class MapGridGUI
violetavk	2016-02-20	Merge pull request #16 from 4ND4/master
yakubu	2016-02-21	Some tiny tweaks to traffic light and an animation to show switching of the lights
violetavk	2016-02-21	Merge pull request #17 from mugu101/master
4ND4	2016-02-21	Add class MapGridGUI
4ND4	2016-02-21	Resource folder

4ND4	2016-02-21	MapGridGUITestMain
violetavk	2016-02-21	Merge pull request #18 from 4ND4/master
4ND4	2016-02-21	CarGUI Implementation
violetavk	2016-02-21	Merge pull request #19 from 4ND4/master
rawanmoh	2016-02-21	read trafficLight
rawanmoh	2016-02-22	readTrafficLight test
Violet	2016-02-22	Made Ticker class a singleton class, use Ticker.getInstance() to get the ticker
jia0627	2016-02-22	Report2
rawanmoh	2016-02-22	Add moveVehicle and its test
rawanmoh	2016-02-22	TODO
violetavk	2016-02-22	Merge pull request #20 from Jia0627/master
violetavk	2016-02-22	Merge pull request #21 from RawanMoh/master
yakubu	2016-02-22	Debug colour change
violetavk	2016-02-22	Merge pull request #22 from mugu101/master
Violet	2016-02-22	Fixed some moveCar bugs in Vehicle, car didn't move thru the lane before
Violet	2016-02-22	Adding the beginnings of ticker integration with car, still some strange behaviour left over
Violet	2016-02-22	Fixed traffic light blink problems
Violet	2016-02-22	Fixed some Ticker related bugs for Vehicle, working slightly better now
jia0627	2016-02-22	Progress Report3
jia0627	2016-02-22	getLaneOptions for Intersection
violetavk	2016-02-22	Merge pull request #23 from Jia0627/master
rawanmoh	2016-02-22	Add vehicleTurn, it turns and does not choose same lane but still there are some problems
rawanmoh	2016-02-22	try commit
rawanmoh	2016-02-23	getLaneOptions
Violet	2016-02-23	Merge branch 'RawanMoh-master'
Violet	2016-02-23	merge of Intersection class
Violet	2016-02-23	Integrated Ticker with Vehicle fully (hopefully)

Violet	2016-02-23	Fixed bug in MapGrid when adding intersection and fixed bug in Intersection addEastRoad
Violet	2016-02-23	Added Map serialization, Maps can now save and load
rawanmoh	2016-02-23	getLaneOption is complete.
Violet Avkhukova	2016-02-23	Merge pull request #25 from RawanMoh/master
rawanmoh	2016-02-23	getLaneOption Test.
rawanmoh	2016-02-23	needs to modify getRoad and getIntersection methods
rawanmoh	2016-02-23	added lane.setIntersection and its test
yakubu	2016-02-23	seperation of functionality: ran into some problems
rawanmoh	2016-02-24	modify getLaneOptions and added its test also tests for lane.getIntersection, intersection.getRoad and vehicleTurn
Violet Avkhukova	2016-02-24	Merge pull request #26 from RawanMoh/master
Jia	2016-02-24	simulationModeScreen
jia0627	2016-02-24	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
Violet Avkhukova	2016-02-24	Merge pull request #27 from Jia0627/master
4ND4	2016-02-24	Map Dimension changeable Added a resize Factor Programmatically draw roads according to amount of lanes
Violet Avkhukova	2016-02-24	Merge pull request #28 from 4ND4/master
jia0627	2016-02-24	Report4
Violet Avkhukova	2016-02-24	Merge pull request #29 from Jia0627/master
rawanmoh	2016-02-24	Add ROAD as parameter in Lane
Violet Avkhukova	2016-02-24	Merge pull request #30 from RawanMoh/master
yakubu	2016-02-24	Separated test functionality from gui logic. created new light but controller isn’t able to simultaneously control both.Think it has something to do with threads.
yakubu	2016-02-24	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
Violet Avkhukova	2016-02-24	Merge pull request #31 from mugu101/master

4ND4	2016-02-24	Car working properly on road
Violet Avkhukova	2016-02-25	Merge pull request #32 from 4ND4/master
Violet	2016-02-26	Added getComponent method to Map
felix	2016-02-26	CarGUI Implementation
4ND4	2016-02-26	MapGrid Improvements
Violet Avkhukova	2016-02-26	Merge pull request #33 from 4ND4/master
4ND4	2016-02-26	FixedMap hc serial
Violet Avkhukova	2016-02-26	Merge pull request #34 from 4ND4/master
4ND4	2016-02-26	Map serial change
Violet Avkhukova	2016-02-26	Merge pull request #35 from 4ND4/master
Jia	2016-02-26	map creation
Violet Avkhukova	2016-02-26	Merge pull request #36 from Jia0627/master
Jia	2016-02-26	report 5
4ND4	2016-02-26	latest changes
Violet Avkhukova	2016-02-26	Merge pull request #37 from Jia0627/master
Violet Avkhukova	2016-02-26	Merge pull request #38 from 4ND4/master
4ND4	2016-02-28	Map Improvements
Violet Avkhukova	2016-02-28	Merge pull request #39 from 4ND4/master
yakubu	2016-02-28	Getting current coordinate improvements and tests
Violet Avkhukova	2016-02-28	Merge pull request #40 from mugu101/master
4ND4	2016-02-29	Fixed map movement
4ND4	2016-02-29	Fixed map movement
felix	2016-02-29	Fixed map movement
felix	2016-02-29	Fixed map movement
felix	2016-02-29	Fixed map movement
felix	2016-02-29	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-01	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-01	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-01	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator

rawanmoh	2016-03-01	coordinate
4ND4	2016-03-01	Car now draws on the corresponding lane
4ND4	2016-03-01	Car now draws on the corresponding lane
rawanmoh	2016-03-01	some tests getLaneOptions turnVi
rawanmoh	2016-03-01	some tests getLaneOptions turnVi
rawanmoh	2016-03-02	some tests getLaneOptions turnVi
Violet Avkhukova	2016-03-02	Merge pull request #41 from RawanMoh/master
felix	2016-03-02	Car now draws on the corresponding lane
felix	2016-03-02	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
4ND4	2016-03-02	Added RoadIndex
Violet Avkhukova	2016-03-02	Merge pull request #42 from 4ND4/master
Violet	2016-03-02	Adding Intersection Decorator things and bug fix in Ticker
Violet	2016-03-02	updates to trafficlightcontroller
Violet	2016-03-02	fixed a bug in Intersection class
Violet	2016-03-02	updates to intersection controller
Violet	2016-03-02	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
rawanmoh	2016-03-02	some tests getLaneOptions turnVi
Violet	2016-03-02	merged changes
felix	2016-03-02	Added RoadIndex
Violet Avkhukova	2016-03-02	Merge pull request #44 from 4ND4/master
Violet	2016-03-02	Added serialVersionUID to all serializable classes
Violet	2016-03-02	Updated fixed map, and fixed bug in Intersection setEastRoad
jia	2016-03-02	report 6
rawanmoh	2016-03-02	remove Road from Lane constructor
Violet Avkhukova	2016-03-02	Merge pull request #45 from Jia0627/master
Violet Avkhukova	2016-03-02	Merge pull request #46 from RawanMoh/master
Violet	2016-03-02	Fixed serialization issue, hopefully maps load across machines now
rawanmoh	2016-03-02	set intersection for lanes
Violet Avkhukova	2016-03-02	Merge pull request #47 from RawanMoh/master
yakubu	2016-03-02	Rotate Method and Test
felix	2016-03-02	Fixed car GUI

rawanmoh	2016-03-02	change set intersection for north and west lane to be compatible with MapGridGUI
Violet Avkhukova	2016-03-02	Merge pull request #48 from mugu101/master
4ND4	2016-03-02	Added TODO
jia	2016-03-02	SetMapDimension
felix	2016-03-02	Added RoadIndex
felix	2016-03-02	Added RoadIndex
Violet	2016-03-02	Merge branch 'RawanMoh-master'
Violet Avkhukova	2016-03-02	Merge pull request #50 from Jia0627/master
Violet	2016-03-02	Merge branch 'master' of https://github.com/4ND4/LondonSW_trafficsimulator into 4ND4-master
Violet	2016-03-02	Merge branch '4ND4-master'
Violet	2016-03-02	refactored trafficlightgui to decorator
Violet Avkhukova	2016-03-02	Merge pull request #52 from violetavk/traffic-light-colours
4ND4	2016-03-03	Added bigger map
Violet Avkhukova	2016-03-03	Merge pull request #53 from 4ND4/master
4ND4	2016-03-03	Changed car colour
4ND4	2016-03-03	Added lane status
felix	2016-03-03	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet Avkhukova	2016-03-03	Merge pull request #54 from 4ND4/master
felix	2016-03-03	test
4ND4	2016-03-03	added an example test.java of the car turning
jia0627	2016-03-03	SetMapDimension
Violet Avkhukova	2016-03-03	Merge pull request #55 from Jia0627/master
felix	2016-03-04	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
rawanmoh	2016-03-04	Added lane state in getLaneOptions
Violet Avkhukova	2016-03-04	Merge pull request #56 from RawanMoh/master
felix	2016-03-04	Added Interfase Vehicle
4ND4	2016-03-04	Decorated Vehicle
felix	2016-03-04	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-04	Decorated Vehicle

Violet Avkhukova	2016-03-04	Merge pull request #57 from 4ND4/master
yakubu	2016-03-04	Road closed image
4ND4	2016-03-04	Single map implementation
Violet Avkhukova	2016-03-04	Merge pull request #58 from 4ND4/master
yakubu	2016-03-04	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
yakubu	2016-03-04	Road closed image
Violet Avkhukova	2016-03-04	Merge pull request #59 from mugu101/master
rawanmoh	2016-03-04	fix VehicleTurn bug
Violet Avkhukova	2016-03-04	Merge pull request #60 from RawanMoh/master
jia	2016-03-04	pre-made map
felix	2016-03-04	Single map implementation
yakubu	2016-03-04	Random cell method
yakubu	2016-03-04	Add step method for coordinates
Violet Avkhukova	2016-03-04	Merge pull request #61 from Jia0627/master
Violet Avkhukova	2016-03-04	Merge pull request #62 from 4ND4/master
Violet Avkhukova	2016-03-04	Merge pull request #63 from mugu101/master
Violet	2016-03-04	Removed commented code from Intersection
Violet	2016-03-04	Adding RxJava and RxJavaFx libraries
Violet	2016-03-04	Added new Ticker refactor
Violet	2016-03-05	Integrated TrafficLight and Intersection with new Ticker, and fully functioning GUIs for each
Violet	2016-03-05	Vehicle fully integrated with new Ticker
Violet Avkhukova	2016-03-05	Merge pull request #64 from violetavk/ticker-refactor
4ND4	2016-03-05	Rules for intersection movement (using transition animation)
felix	2016-03-05	Rules for intersection movement (using transition animation)
felix	2016-03-05	Rules for intersection movement (using transition animation)
felix	2016-03-05	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator

Violet Avkhukova	2016-03-05	Merge pull request #65 from 4ND4/master
rawanmoh	2016-03-06	Added map
rawanmoh	2016-03-06	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
Violet Avkhukova	2016-03-06	Merge pull request #66 from RawanMoh/master
felix	2016-03-07	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
Violet Avkhukova	2016-03-07	Merge pull request #67 from 4ND4/master
jia0627	2016-03-07	Report 7
Violet Avkhukova	2016-03-07	Merge pull request #68 from Jia0627/master
rawanmoh	2016-03-07	fix vehicleTurn, If there is no lane to go, the vehicle stops
Violet	2016-03-07	Merge branch ‘RawanMoh-master’
Violet	2016-03-07	merge with rawan laneoptions code
Violet	2016-03-07	fixed messed up merge for drawTestMapExample, hopefully
rawanmoh	2016-03-08	Added JavaDoc to Vehicle Class
Violet Avkhukova	2016-03-08	Merge pull request #70 from RawanMoh/master
Violet	2016-03-08	Integrated traffic lights with map, cars do not yet listen to them
Violet Avkhukova	2016-03-08	Merge pull request #71 from violetavk/intersection-integration
Violet	2016-03-08	Fixed arrows to show properly and refactored the method, and set test map dimension to 22x22
rawanmoh	2016-03-08	cars listen to traffic light
jia0627	2016-03-08	simulation start&reset trigger
Violet Avkhukova	2016-03-08	Merge pull request #72 from RawanMoh/master
Violet	2016-03-08	Simulation controller added from Jias code
Violet	2016-03-08	Merge branch ‘Jia-master’
Violet	2016-03-08	Merge branch ‘master’ of https://github.com/Jia0627/LondonSW_trafficsimulator into Jia-master
Violet	2016-03-08	Merge branch ‘Jia-master’
Violet	2016-03-08	fixed minor bug in readTrafficLight and added some documentation to some methods

yakubu	2016-03-08	Coordinate class documentation
Violet Avkhukova	2016-03-08	Merge pull request #74 from mugu101/master
rawanmoh	2016-03-09	control the movement of more than car organize MapGridGUITestMain code
Violet Avkhukova	2016-03-09	Merge pull request #75 from RawanMoh/master
rawanmoh	2016-03-09	divided drawTestMapExample into one lane and two lane..
Violet Avkhukova	2016-03-09	Merge pull request #76 from RawanMoh/master
yakubu	2016-03-09	Created ambulance which inherits from vehicle
4ND4	2016-03-09	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet Avkhukova	2016-03-09	Merge pull request #77 from mugu101/master
Violet	2016-03-10	Deleted CarDecorator and TrafficLightAnimation, added serialization to intersectiondecorator and trafficlightdecorator
Violet	2016-03-10	Fixed merge conflicts
rawanmoh	2016-03-10	fix a wrong coordinate for road 7 in drawTestMapExample
Violet Avkhukova	2016-03-10	Merge pull request #79 from RawanMoh/master
Violet	2016-03-10	WORK IN PROGRESS, some cars moving in the proper lanes
4ND4	2016-03-10	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-10	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-11	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-11	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-11	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-11	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet Avkhukova	2016-03-11	Merge pull request #81 from 4ND4/master
Violet	2016-03-11	Fixed animation for all cars, it now works with any ticker speed

rawanmoh	2016-03-11	generate Vehicle
yakubu	2016-03-11	We would have a button to spawn an ambulance:on single and double click
Violet	2016-03-11	Merged new animation on top of old code
Violet Avkhukova	2016-03-11	Merge pull request #82 from mugu101/master
Violet	2016-03-11	Animation works with multiple cars
Violet	2016-03-11	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet	2016-03-11	Merged with ambulance code
rawanmoh	2016-03-11	Added generateVehicle method
Violet Avkhukova	2016-03-11	Merge pull request #83 from RawanMoh/master
jia0627	2016-03-12	Report8
Violet Avkhukova	2016-03-12	Merge pull request #84 from Jia0627/master
4ND4	2016-03-13	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
rawanmoh	2016-03-13	Added some validation in setCurrentCell and setCurrentLane Added Exceptions in setCurrentCell and setCurrentLane Added some javaDoc in vehicle Class
Violet Avkhukova	2016-03-13	Merge pull request #85 from 4ND4/master
Violet	2016-03-13	Trying to fix traffic light serialization
Violet	2016-03-13	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet	2016-03-13	Fixed merge with rawan's updates
4ND4	2016-03-14	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet Avkhukova	2016-03-14	Merge pull request #87 from 4ND4/master
rawanmoh	2016-03-15	change moveVehicle form void to boolean added new test in LaneTest fix move out of intersection bug
Violet	2016-03-15	Traffic lights now worked in loaded maps from file
Violet	2016-03-15	Added the example map as a file, this one is a complete map
Violet	2016-03-15	Merged with fixed move out of intersection
jia0627	2016-03-15	Report9
rawanmoh	2016-03-15	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator

rawanmoh	2016-03-15	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
rawanmoh	2016-03-16	Added car ID
Violet Avkhukova	2016-03-16	Merge pull request #89 from RawanMoh/master
felix	2016-03-16	Added some functionalities
Violet	2016-03-16	Improved getting the width and size from user for mapmaker mode
felix	2016-03-16	Added some functionalities
felix	2016-03-16	Added some functionalities
felix	2016-03-16	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
4ND4	2016-03-16	Added the click functionality to enable and disable roads
4ND4	2016-03-16	Added the click functionality to enable and disable lanes (clicking on arrow)
felix	2016-03-16	Added the click functionality to enable and disable lanes (clicking on arrow)
yakubu	2016-03-16	Changes to Ambulance: Works with a single click. Also ambulance behaviour is fine unless we would like to change . . .
Violet Avkhukova	2016-03-16	Merge pull request #90 from 4ND4/master
yakubu	2016-03-16	Generating new ambulance on click and removing the old one using rawans car generate method
4ND4	2016-03-16	Cars abandon Simulation when they get to a road without an intersection
yakubu	2016-03-16	Able to create new intstances of ambulance. However not able to remove them. Still working on it.
Violet Avkhukova	2016-03-16	Merge pull request #91 from 4ND4/master
Violet Avkhukova	2016-03-16	Merge pull request #92 from mugu101/master
felix	2016-03-16	Cars abandon Simulation when they get to a road without an intersection
4ND4	2016-03-17	Cars now disappear properly
Violet Avkhukova	2016-03-17	Merge pull request #93 from 4ND4/master
Violet	2016-03-17	Can now add intersections in map maker mode
Violet	2016-03-17	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator

rawanmoh	2016-03-17	Added method in lane to read the vehicle in intersection Added lane as a parameter to moveVehicle
Violet Avkhukova	2016-03-17	Merge pull request #94 from RawanMoh/master
4ND4	2016-03-17	Fix bug when traffic light disabled, and lane disabled car stopped forever
4ND4	2016-03-17	Fixed bug for moveVehicle, now the cars don't go on top of each other when a car stops. . . .
Violet Avkhukova	2016-03-17	Merge pull request #95 from 4ND4/master
rawanmoh	2016-03-18	Added method to who turn first
Violet Avkhukova	2016-03-18	Merge pull request #96 from RawanMoh/master
Violet	2016-03-18	Added more to Map maker mode
Violet	2016-03-18	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-18	Fixed bug for moveVehicle, now the cars don't go on top of each other when a car stops. . . .
Violet Avkhukova	2016-03-18	Merge pull request #97 from 4ND4/master
jia0627	2016-03-18	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
jia0627	2016-03-18	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet	2016-03-18	Added more to MapMaker mode and reworked Simulation mode screens
jia0627	2016-03-18	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet	2016-03-18	Adding forgotten SimulationController
yakubu	2016-03-18	Done with ambulance class and a few minor changes
Violet Avkhukova	2016-03-18	Merge pull request #98 from mugu101/master
Violet	2016-03-19	Can now place new map squares on top of old ones, and fixed a bug in Road runsVertically
Violet	2016-03-19	Adding east-west roads and hitting the save button determines which road bits are connected and adds them as one single road

rawanmoh	2016-03-20	Added methods to intersection class, do not do any thing yet added map to laneTest
rawanmoh	2016-03-20	Added new maptest in mapExample
4ND4	2016-03-20	Added Logs to simulation
Violet Avkhukova	2016-03-20	Merge pull request #99 from RawanMoh/master
Violet Avkhukova	2016-03-20	Merge pull request #100 from 4ND4/master
Violet	2016-03-20	Tried something for resize factor
jia0627	2016-03-20	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet	2016-03-21	When saving user built map, it can detect which roads should be merged as one
Violet	2016-03-21	Added JavaDoc to the MapMaker screen
jia0627	2016-03-21	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet	2016-03-21	Added JavaDoc to MapMakerController
jia0627	2016-03-21	update SimulationScreen
Violet	2016-03-21	Small additions to MapMakerScreen
Violet	2016-03-21	Merge branch 'Jia-master'
4ND4	2016-03-21	FIxed issue with car going on top of each other when the cars are not moving
felix	2016-03-21	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
felix	2016-03-21	FIxed issue with car going on top of each other when the cars are not moving and disappear properly.
jia0627	2016-03-21	report 10
rawanmoh	2016-03-21	new methods
Violet Avkhukova	2016-03-21	Merge pull request #104 from Jia0627/master
Violet	2016-03-21	Worked on saving map in map builder, cleaned up some controllers, and deleted unnecessary files
Violet	2016-03-21	Deleted useless map, updated BigMap.map so lane disabling works
Violet	2016-03-21	Added Back button to MapMaker mode
Violet	2016-03-21	Finished map maker mode, can now build a map and run a simulation on it in simulation mode
jia0627	2016-03-21	finish add/delete ambulance

Violet Avkhukova	2016-03-21	Merge pull request #105 from Jia0627/master
Violet	2016-03-21	Changed the Log a little to save them in the logs directory and with filename format of Log_CURRENTDATE
Violet	2016-03-21	Created files for rough drafts for each section of the final report
Violet	2016-03-21	Deleted Simulation class and FixedMap.map because it was broken
Violet	2016-03-21	Added JavaDoc comments to many files
Violet	2016-03-21	Added new preset map called Loops.map
Violet	2016-03-22	Fixed bug in loaded maps for traffic lights, they changed color only with the duration they were made with, now put the duration into the controller so their duration is set there
rawanmoh	2016-03-22	fixing the movement of cars in intersection
Violet	2016-03-22	Added a method to determine the best resize factor for a map, and added JavaDoc for VehicleGUIDecorator and cleaned it up a little
rawanmoh	2016-03-22	added some javaDocs
jia0627	2016-03-22	Add SetTickerInterval dialog
Violet	2016-03-22	Added some checks to prevent users from selecting null width and height for map maker mode and selecting a non-map file to load for simulation mode
Violet	2016-03-22	Some javadoc and some cleanup
Violet	2016-03-22	Merge branch 'Jia-master'
jia0627	2016-03-22	Add TickerInterval validation check; show TickerInterval
jia0627	2016-03-22	Merge branch 'master' of https://github.com/violetavk/LondonSW_trafficsimulator
Violet Avkhukova	2016-03-22	Merge pull request #108 from Jia0627/master
Violet	2016-03-22	SimulationScreen uses suggested resizefactor, and deleted useless MapMaker files from the model
rawanmoh	2016-03-22	vehicle now move properly in intersections added some javaDocs
rawanmoh	2016-03-22	vehicle now move properly in intersections added some javaDocs
jia0627	2016-03-22	Change right part boarderPane style

jia0627	2016-03-22	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
Violet	2016-03-22	Merge branch ‘RawanMoh-master’
Violet Avkhukova	2016-03-22	Merge pull request #111 from Jia0627/master
Violet	2016-03-22	Fixed vehicle turning bug in loaded maps, this is because the Intersection had to be resubscribed to the ticker upon loading a map
jia0627	2016-03-22	Disable slider when simulation stops; Add back button to go back to ModeChoose screen
jia0627	2016-03-22	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
Violet	2016-03-23	Merge branch ‘Jia-master’
Violet	2016-03-23	Had to remove the set tick interval for now, unsure of how to integrate that way
Violet	2016-03-23	Deleted testmap.map
jia0627	2016-03-23	Determine max value of slider dynamically
Violet	2016-03-23	Added remove vehicle functionality from the GUI
Violet	2016-03-23	Merge branch ‘Jia-master’
Violet	2016-03-23	Can now remove cars using the slider in simulation mode
Violet	2016-03-23	Reset button now works
Violet	2016-03-23	Added set traffic light duration button to simulation screen
Violet	2016-03-23	Added some interesting labels to the simulation screen, and fixed bug where simulation didn’t stop after unsubscribing
Violet	2016-03-23	Can now change ticker interval duration for the simulation
Violet	2016-03-23	Changed time label to start after hitting Start button, and to stop after hitting Reset button
4ND4	2016-03-23	Fixed enable/disable lanes
4ND4	2016-03-23	Fixed bug when creating intersection on map making mode
4ND4	2016-03-23	Fixed bug when creating intersection on map making mode
Violet	2016-03-23	Merge branch ‘4ND4-master’
Violet	2016-03-23	Fixed map builder bug because the ticker was null

4ND4	2016-03-23	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
4ND4	2016-03-23	Fixed ambulance add/delete
felix	2016-03-23	Fixed ambulance add/delete
Violet	2016-03-23	Merge branch ‘4ND4-master’
Violet	2016-03-23	Merged with most recent changes for SimulationScreen
Violet	2016-03-23	Finished JavaDoc for the remaining controllers
Violet	2016-03-23	Ambulances aren’t deleted anymore with the slider, and now changing the Number of cars label when adding and deleting an ambulance
Violet	2016-03-23	Added JavaDoc for RoadGUIDecorator, removed some println statements from TrafficLightDeorator, and deleted SliderTest file
Violet	2016-03-24	Number of cars label now updates when a car leaves the system
Violet	2016-03-24	Added JavaDoc for LayoutGUI, and removed an old TODO from ticker
Violet	2016-03-24	Added JavaDoc to IntersectionDecorator and MapGridGUIDecorator
Violet	2016-03-24	Made the Set Traffic Light Duration dialog a bit more user friendly by setting ticks, not milliseconds
Violet	2016-03-24	Added instructions label to simulation screen so user knows they can enable and disable lanes
Violet	2016-03-24	Added draft files for all group members, and deleted some maps
Violet	2016-03-24	Update to readme.md
felix	2016-03-24	Fixed Vehicle Behaviour
Violet Avkhukova	2016-03-24	Merge pull request #117 from 4ND4/master
rawanmoh	2016-03-24	Added JavaDoc to vehicle and lane class and remove some unused codes
Violet	2016-03-24	Merge branch ‘RawanMoh-master’
Violet	2016-03-24	Fixed traffic light bug, any maps made before this fix have to be remade
Violet	2016-03-24	Added a cool map called FourSquares
Violet	2016-03-24	Added enable and disable traffic lights functionality
rawanmoh	2016-03-24	fixed car movement in one cell lane bug

Violet Avkhukova	2016-03-24	Merge pull request #119 from RawanMoh/master
Violet	2016-03-24	Added a label with the statistic of how long vehicles spend standing in the simulation
Violet	2016-03-24	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
jia0627	2016-03-25	Report 11
jia0627	2016-03-25	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
Violet	2016-03-25	Changed the initial screens so that fxml is no longer used, because they didn’t work in an exported jar file, and they look nicer now
Violet Avkhukova	2016-03-25	Merge pull request #120 from Jia0627/master
4ND4	2016-03-25	Delete Wood.png
4ND4	2016-03-25	Delete car.png
4ND4	2016-03-25	Delete car.svg
4ND4	2016-03-25	Delete Roadclosed.png
Violet	2016-03-27	Adding Ticker writeup to my draft, still a work in progress
Violet	2016-03-27	Merge branch ‘master’ of https://github.com/violetavk/LondonSW_trafficsimulator
4ND4	2016-03-28	Added files via upload
rawanmoh	2016-03-28	report draft
Violet Avkhukova	2016-03-28	Merge pull request #121 from violetavk/implementation
Violet	2016-03-28	Adding more to violet draft, still work in progress
4ND4	2016-03-28	Create readme.txt
4ND4	2016-03-28	Delete implementation_evaluation_santiago.zip
4ND4	2016-03-28	Added files via upload
4ND4	2016-03-28	Update santiago.tex
4ND4	2016-03-28	Added files via upload
jia0627	2016-03-28	draft for SimulationScreen and teamwork parts
Violet Avkhukova	2016-03-28	Merge pull request #122 from Jia0627/master

yakubu	2016-03-29	added two new files (draft and literature). 1. Literature.tex holds the references of articles i consulted for the review. 2. Draft.tex allows all sections to be compiled in one file. All you have to do is include the section you want to be compiled in the draft file.
Violet Avkhukova	2016-03-29	Merge pull request #123 from mugu101/master
Violet	2016-03-29	Adding final report, still gluing all the bits together and work in progress
4ND4	2016-03-29	Update santiago.tex
Violet	2016-03-29	Updates to final report
Violet	2016-03-29	Stuff about statistics and traffic management for the report
jia0627	2016-03-29	talk about more for slider
Violet Avkhukova	2016-03-29	Merge pull request #124 from Jia0627/master
Violet	2016-03-29	Working on some vehicle descriptions, added section for general evaluation
Violet	2016-03-29	Upadates to final report, and added image

B Source Code

```
        package londonsw;

        import londonsw.controller.StartUpController;

/**
 * This is the main class that first gets executed by the system
 * It starts the View components (and from there will branch to either simulatio
n or map−making)
 */
public class SystemApp {
        public static void main(String[] args) throws Exception {
                StartUpController sc = StartUpController.getInstance();
                sc.startSoftware(args);
        }
}
```

```java
package londonsw.controller;


import londonsw.model.simulation.components.Intersection;
import londonsw.model.simulation.components.vehicles.Vehicle;
import londonsw.view.simulation.IntersectionDecorator;

import java.util.ArrayList;
import java.util.HashMap;
import java.util.Map;


public class IntersectionController {
    private static Map<Intersection,IntersectionDecorator> intersections = new H
ashMap<Intersection,IntersectionDecorator>();
    private static ArrayList<Intersection> allIntersections = new ArrayList<>();

    /**
     * Prevents instantiation of this class
     */
    protected IntersectionController() {  }

    /**
     * Register an instance of an Intersection to and IntersectionDecorator, and
 adds the Intersection to a list to keep
     * track of
     * @param i the instance of Intersection to register
     * @param gui the instance of IntersectionDecorator for that intersection
     */
    public static void addIntersectionAndDecoratorPair(Intersection i, Intersect
ionDecorator gui) {
        intersections.put(i,gui);
        allIntersections.add(i);
    }

    /**
     * Retrieve the decorator for that specific Intersection
     * @param i the Intersection to get the decorator for
     * @return the decorator associated with that Intersection
     */
    public static IntersectionDecorator getIntersectionDecoratorForIntersection(
Intersection i) {
        return intersections.get(i);
    }

    /**
     * Gets all Intersections in the system
     * @return ArrayList of all Intersections in the system
     */
    public ArrayList<Intersection> getAllIntersections() {
        return allIntersections;
    }


    /**
     * This method is used for determining which vehicle will turn first in an i
ntersection. By generating priorities,
     * this will prevent cars from driving into each other in intersections.
     * @param intersection the intersection where the vehicles are
     * @param vehicles array list of vehicles with priorities set
     * @return true if this method succeeds (always true)
     * @throws Exception
     */
    public static boolean vehicleTurnFirst(Intersection intersection, ArrayList<
Vehicle> vehicles) throws Exception {
        ArrayList<Integer>  randomPriority = (ArrayList < Integer>) intersection
.generateRandom().clone();
        intersection.vehicleTurnFirst(intersection.giveVehiclePriorities(randomP
riority));

        return true;
    }


}
```

```java
package londonsw.controller;

import javafx.stage.Stage;
import londonsw.view.mapcreation.ComponentType;
import londonsw.view.mapcreation.MapMakerScreen;

/**
 * The controller for the Map making aspect of this software
 */
public class MapMakerController {

    private int width;
    private int height;
    private Stage primaryStage;

    private static ComponentType currentFocused;
    private static ComponentType previousFocused;

    /**
     * Creates an instance of a MapMakerController with a stage in which to draw
 the Map making screen
     * @param primaryStage the stage in which to draw the Map making screen
     */
    public MapMakerController(Stage primaryStage) {
        this.primaryStage = primaryStage;
    }

    /**
     * Tells this controller what width and height the user chose for their map
     * @param width the width of the user’s new map
     * @param height the height of the user’s new map
     */
    public void setWidthAndHeight(int width, int height) {
        this.width = width;
        this.height = height;
    }

    /**
     * Draws the screen using the stage given and displays it to the user
     * @throws Exception
     */
    public void drawScreen() throws Exception{
        MapMakerScreen mapMakerScreen = new MapMakerScreen(width, height);
        mapMakerScreen.drawScreen(primaryStage);
    }

    /**
     * Get the width the user chose for their new map
     * @return width of the map
     */
    public int getWidth() {
        return width;
    }

    /**
     * Get the height the user chose for their map
     * @return height of the map
     */
    public int getHeight() {
        return height;
    }

    /**
     * Gets what the current focused is in the screen. This is what the user cli
cked last in the screen. It is of type
     * ComponentType enum, which can be a RoadNS image, Map_Square, Nothing, etc
     * @return ComponentType enum of what the user clicked last
     */
    public static ComponentType getCurrentFocused() {
        return currentFocused;
    }

    /**
     * Sets the current focused in the map, this is set after the user clicks so
mething
     * @param focused what was last clicked on by the user, converted to type en
um ComponentType
     */
    public static void setCurrentFocused(ComponentType focused) {
        currentFocused = focused;
    }

    /**
     * Gets what the user previously clicked (the click before the current click
)
     * @return ComponentType of what was clicked on the click before the last
     */
    public static ComponentType getPreviousFocused() {
        return previousFocused;
    }

    /**
     * Sets the previously clicked before last item
     * @param prev sets the click before the last click to what was focused, con
verted to type ComponentType
     */
    public static void setPreviousFocused(ComponentType prev) {
        previousFocused = prev;
    }

}
```

```java
package londonsw.controller;

import javafx.stage.Stage;
import londonsw.model.simulation.Log;
import londonsw.model.simulation.Map;
import londonsw.view.simulation.SimulationScreen;

import java.text.SimpleDateFormat;
import java.util.Date;

/**
 * This is the controller for simulations in our View. It draws the screen and g
enerates the Log for the simulation.
 */
public class SimulationController {

    private Stage primaryStage;
    private String mapName;
    private String logFileName;

    /**
     * Creates a new SimulationController to control the simulation
     * @param primaryStage the stage in which to display the new screen
     */
    public SimulationController(Stage primaryStage) {
        this.primaryStage = primaryStage;
    }

    /**
     * Sets the name of the map that the user wants to open
     * @param mapName name of map file that user wants to simulate vehicles on
     */
    public void setMapName(String mapName) {
        this.mapName = mapName;
    }

    /**
     * Draws the screen where the simulation will be taking place, and creates t
he Log to log all activity
     * in the simulation
     * @throws Exception
     */
    public void drawScreen() throws Exception {
        Map map = Map.loadMap(mapName);
        SimulationScreen screen = new SimulationScreen(map);
        screen.drawScreen(primaryStage);
        generateLogFileName();
        Log log = new Log(getLogFileName());
    }

    /**
     * Get the name of the log file for that specific simulation
     * @return
     */
    public String getLogFileName() {
        return logFileName;
    }

    /**
```

```
     * Generates a file name for the log file for that simulation. It is in the
format
     * Log_DATE.log, where DATE is the YEAR-MONTH-DAY-HOUR-MINUTES-SECONDS
     */
    public void generateLogFileName() {
        String date = new SimpleDateFormat("yyyy-MM-dd-HH-mm-ss").format(new Dat
e());
        logFileName = "Log_" + date;
    }

}
```

```
package londonsw.controller;


import javafx.application.Application;
import javafx.application.Platform;
import javafx.collections.FXCollections;
import javafx.collections.ObservableList;
import javafx.event.ActionEvent;
import javafx.fxml.FXMLLoader;
import javafx.geometry.Insets;
import javafx.geometry.Pos;
import javafx.scene.Node;
import javafx.scene.Parent;
import javafx.scene.Scene;
import javafx.scene.control.*;
import javafx.scene.layout.GridPane;
import javafx.scene.layout.VBox;
import javafx.scene.text.Font;
import javafx.scene.text.FontWeight;
import javafx.stage.FileChooser;
import javafx.stage.Stage;
import java.io.File;

import javafx.stage.StageStyle;
import javafx.util.Pair;
import londonsw.model.simulation.Ticker;

//import java.awt.*;
import java.io.IOException;
import java.util.Optional;

/**
 *  This is the controller that gets called by the main SystemApp class. This co
ntroller initiates all GUI screens.
 */
@SuppressWarnings("Duplicates")
public class StartUpController extends Application {

    private static StartUpController instance;

    public StartUpController() { }

    public static StartUpController getInstance() {
        if(instance == null)
            instance = new StartUpController();
        return instance;
    }

    public void startSoftware(String[] args) {
        launch(args);
    }

    /**
     * This is the first method that gets called in the system. It loads the Sta
rtScreen fxml file, which contains
     * the START button.
     * @param primaryStage the stage that initially loads
     * @throws Exception
     */
    @Override
    public void start(Stage primaryStage) throws Exception {
        primaryStage.setTitle("LondonSW Traffic Simulator");

        VBox vBox = new VBox();
        vBox.setPrefSize(600,400);
        vBox.setSpacing(10);
        vBox.setStyle("-fx-background-color:papayawhip");
        vBox.setAlignment(Pos.CENTER);

        Label londonSWLabel = new Label("London SW");
        londonSWLabel.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 20));
        Label trafficSimLabel = new Label("Traffic Simulator");
        trafficSimLabel.setFont(Font.font("System Bold Italic", FontWeight.EXTRA_BOLD
, 22));
        trafficSimLabel.setPadding(new Insets(0,0,50,0));
        Button startButton = new Button("Start");
        startButton.setPrefSize(300,150);
        startButton.setStyle("-fx-base:Gold");
        startButton.setFont(Font.font("System Bold Italic", FontWeight.EXTRA_BOLD, 26
));

        vBox.getChildren().add(londonSWLabel);
        vBox.getChildren().add(trafficSimLabel);
        vBox.getChildren().add(startButton);

        Scene scene = new Scene(vBox);
        primaryStage.setScene(scene);
        primaryStage.setResizable(false);
        primaryStage.show();
        primaryStage.centerOnScreen();

        startButton.setOnMouseClicked(click -> {
            goToChooseModeScreen(primaryStage);
        });
    }

    /**
     * This is the method that gets called when the user hits the START button o
n the initial screen. It
     * loads the "Choose Mode" screen, which gives 2 options: Opening a pre-made
 map, or users building their own map.
     * @param primaryStage the stage to display the screen in
     */
    public void goToChooseModeScreen(Stage primaryStage) {
        VBox vBox = new VBox();
        vBox.setPrefSize(600,400);
        vBox.setSpacing(50);
        vBox.setStyle("-fx-background-color:papayawhip");
        vBox.setAlignment(Pos.CENTER);
        Platform.runLater(() -> vBox.requestFocus());

        Button openMap = new Button("Open a Pre-made Map");
        openMap.setPrefSize(300, 90);
        openMap.setStyle("-fx-base:Gold");
        openMap.setFont(Font.font("System Bold Italic", FontWeight.EXTRA_BOLD, 16));

        Button makeMap = new Button("Make a new Map");
        makeMap.setPrefSize(300, 90);
        makeMap.setStyle("-fx-base:Gold");
        makeMap.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 16));

        vBox.getChildren().add(openMap);
        vBox.getChildren().add(makeMap);

        Scene scene = new Scene(vBox);
        primaryStage.setScene(scene);

        openMap.setOnMouseClicked(click -> {
            try {
                goToSimulationMode(primaryStage);
            } catch (Exception e) {
                e.printStackTrace();
            }
        });

        makeMap.setOnMouseClicked(click -> {
            goToMapMakerMode(primaryStage);
        });
    }

    /**
     * When the user click "Choose Pre-made map..." button, it will go to Simula
tionMode screen. It will first
     * prompt the user to open a file (only Map files are allowed to be opened),
 set a ticker interval speed,
     * and then it will go to draw the simulation mode screen.
     * @param primaryStage the click that caused this method invocation
     * @throws Exception
     */
    public void goToSimulationMode(Stage primaryStage) throws Exception {
        FileChooser chooser=new FileChooser();
        chooser.setTitle("Open Map");
        chooser.getExtensionFilters().add(new FileChooser.ExtensionFilter("Map Fi
le (*.map)", "*.map"));
        File file = chooser.showOpenDialog(new Stage());


        if(file!=null)
        {
//            String mapName = file.getName();
            String mapName = file.getAbsolutePath();


            Dialog<Long> dialog = new Dialog<>();
            dialog.setTitle("Choose Ticker Interval Duration");
            dialog.setHeaderText("Choose a duration (in milliseconds) for\nthe ticker in the system.")
;
            dialog.setGraphic(null);
            dialog.getDialogPane().getButtonTypes().addAll(ButtonType.OK);
            dialog.initStyle(StageStyle.UNDECORATED);

            GridPane grid = new GridPane();
            grid.setHgap(10);
            grid.setVgap(10);
            grid.setPadding(new Insets(20, 80, 10, 10));
            grid.add(new Label("Duration: "), 0, 0);
            Spinner<Double> spinner = new Spinner<Double>(100, 2000, Ticker.getT
ickInterval(), 100);
            grid.add(spinner, 1, 0);
            dialog.getDialogPane().setContent(grid);
            Platform.runLater(() -> spinner.requestFocus());

            dialog.setResultConverter(dialogButton -> {
                if(dialogButton == ButtonType.OK) {
                    double value =  spinner.getValue();
                    return (long) value;
                }
                return null;
            });

            Optional<Long> result = dialog.showAndWait();
            result.ifPresent(aLong -> {
                Ticker.setTickInterval(aLong);
                Ticker.start();
            });

            //Decorate map to extend to GUI functionality
            SimulationController simulationController = new SimulationController
(primaryStage);
            simulationController.setMapName(mapName);
            simulationController.drawScreen();
        }
    }

    /**
     * This method gets called when the user chooses to go to Map Maker mode. It
 will prompt the user for
     * the width and height that they want for their new map, in the range from
5 to 30 for both width and
     * height. It will then bring the user to the screen where they can build th
e map.
     * @param primaryStage the click event that caused this method invocation
     */
    public void goToMapMakerMode(Stage primaryStage) {
        Dialog<Pair<String, String>> dialog = new Dialog<>();
        dialog.setTitle("Choose Map Size");
        dialog.setHeaderText("Choose new map’s width and height");
        dialog.setGraphic(null);

        GridPane grid = new GridPane();
        grid.setHgap(10);
        grid.setVgap(10);
        grid.setPadding(new Insets(20, 150, 10, 10));

        dialog.getDialogPane().getButtonTypes().addAll(ButtonType.OK, ButtonType
.CANCEL);

        ObservableList<Integer> choices = FXCollections.observableArrayList();
        for(int i = 5; i <= 30; i++) {
            choices.add(i);
        }

        ChoiceBox<Integer> widthBox = new ChoiceBox<>();
        widthBox.setItems(choices);
        widthBox.setMinWidth(100);
        Platform.runLater(() -> widthBox.requestFocus());
        ChoiceBox<Integer> heightBox = new ChoiceBox<>();
        heightBox.setItems(choices);
        heightBox.setMinWidth(100);

        grid.add(new Label("Width:"), 0, 0);
        grid.add(widthBox, 1, 0);
        grid.add(new Label("Height:"), 0, 1);
        grid.add(heightBox, 1, 1);

        dialog.getDialogPane().setContent(grid);

        Button doneBtn = (Button) dialog.getDialogPane().lookupButton(ButtonType
.OK);
        doneBtn.setDisable(true);
        doneBtn.disableProperty().bind(
                widthBox.valueProperty().isNull()
                .or(heightBox.valueProperty().isNull())
        );

        dialog.setResultConverter(dialogButton -> {
            if(dialogButton == ButtonType.OK) {
                return new Pair<>(widthBox.getValue().toString(),heightBox.getVa
lue().toString());
            }
            return null;
        });

        Optional<Pair<String, String>> result = dialog.showAndWait();

        result.ifPresent(widthAndHeight -> {
            int width = Integer.parseInt(widthAndHeight.getKey());
            int height = Integer.parseInt(widthAndHeight.getValue());

            MapMakerController mapMakerController = new MapMakerController(prima
ryStage);
            mapMakerController.setWidthAndHeight(width,height);
            try {
                mapMakerController.drawScreen();
            } catch (Exception e) {
                e.printStackTrace();
            }
        });
    }

}
```

```
package londonsw.controller;

import londonsw.model.simulation.components.LightColour;
import londonsw.model.simulation.components.TrafficLight;
import londonsw.view.simulation.TrafficLightDecorator;

import java.util.ArrayList;
import java.util.HashMap;
import java.util.Map;

/**
 * Controls all the traffic lights. This gets notified when the traffic light ch
anges in the model, and it
 * does the necessary work to change the GUI to display the new model.
 */
public class TrafficLightController {

    private Map<TrafficLight, TrafficLightDecorator> trafficLights;
    private ArrayList<TrafficLight> allLights;
    private long DURATION;
    private boolean lightsEnabled;

    private static TrafficLightController instance;

    /**
     * Creates a new instance of a TrafficLightController. It is set to protecte
d so that the creation of this
     * controller is controlled. This class follows the singleton pattern, so th
ere can be at most one instance
     * of this class in the system.
     */
    protected TrafficLightController() {
        trafficLights = new HashMap<>();
        allLights = new ArrayList<>();
        DURATION = 3000;
        lightsEnabled = true;
    }

    /**
     * Gives an instance of this class. This is what needs to be called if an in
stance is needed. If there is
     * not an instance created, it creates a new one, otherwise it returns an ex
isting instance.
     * @return
     */
    public static TrafficLightController getInstance() {
        if(instance == null) {
            instance = new TrafficLightController();
        }
        return instance;
    }

    /**
     * Gets whether the traffic lights are enabled or not
     * @return true if all traffic lights are working and enabled, false otherwi
se
     */
    public boolean areLightsEnabled() {
        return lightsEnabled;
    }

    /**
     * Sets the lights boolean to true. Useful if re-loading a map and wanting t
o go back to default state.
     */
    public void setLightsToEnabled() {
        lightsEnabled = true;
    }

    /**
     * Disables or enables all traffic lights in the system. If traffic lights a
re disabled, cars will
     * move freely without stopping anywhere. If enabled, they listen to the tra
ffic lights.
     * @param disable true disables the lights, false enables the lights
     */
    public void disableLights(boolean disable) {
        if(disable) {
            lightsEnabled = false;
            for(TrafficLight t : allLights) {
                TrafficLightDecorator decorator = trafficLights.get(t);
                if(decorator != null)
                    decorator.hideCircle(true);
            }
        }
        else {
            lightsEnabled = true;
            for(TrafficLight t : allLights) {
                TrafficLightDecorator decorator = trafficLights.get(t);
                if(decorator != null)
                    decorator.hideCircle(false);
            }
        }
    }

    /**
     * Creates a new TrafficLightDecorator for the given TrafficLight
     * @param tl the TrafficLight for which to create the decorator
     * @return the newly created decorated for that TrafficLight
     */
    public TrafficLightDecorator createNewDecorator(TrafficLight tl) {
        return new TrafficLightDecorator(tl);
    }

    /**
     * Called by the TrafficLight (in the model) when the color changes. It tell
s the corresponding
     * TrafficLightDecorator to change its color in the GUI.
     * @param colour the new color to be
     * @param tl a TrafficLight that had its color changed
     */
    public void colourChanged(LightColour colour, TrafficLight tl) {
        if(trafficLights.get(tl) == null) {
            return;
        }
        trafficLights.get(tl).setGUIColour(colour);
    }
    /**
     * Register a TrafficLight (in the model) to a TrafficLightDecorator (in the
 GUI), and add to an
     * ArrayList to keep track of all lights
     * @param tl the TrafficLight instance from the model
     * @param gui the corresponding instance of the TrafficLightDecorator for th
at TrafficLight
     */
    public void addTrafficLightAndDecoratorPair(TrafficLight tl, TrafficLightDec
orator gui) {
        trafficLights.put(tl,gui);
        allLights.add(tl);
    }

    /**
     * If you need to get the decorator for that TrafficLight outside of this cl
ass, use this method
     * @param tl a TrafficLight that you are querying for to get its decorator
     * @return the corresponding TrafficLightDecorator for that TrafficLight
     */
    public TrafficLightDecorator getTrafficLightGUI(TrafficLight tl) {
        return trafficLights.get(tl);
    }

    /**
     * Get a list of all the TrafficLights in the system
     * @return ArrayList of all lights
     */
    public ArrayList<TrafficLight> getAllTrafficLights() {
        return allLights;
    }

    /**
     * Gets the duration length for traffic lights. Traffic lights call this met
hod to know how long to be a certain color.
     * @return length of duration in millis
     */
    public long getDurationLength() {
        return DURATION;
    }

    /**
     * Sets the duration length for traffic lights
     * @param duration the duration for the traffic lights in millis
     */
    public void setDurationLength(long duration) {
        this.DURATION = duration;
    }

    /**
     * Set the duration of all the traffic lights in the map
     * @param duration the duration of the traffic light in milliseconds
     */
    public void setTrafficLightDuration(long duration) {
        for(TrafficLight t : allLights) {
            t.setDuration(duration);
        }
    }
    /**
     * Gets the HashMap of all TrafficLight,TrafficLightDecorator pairs
     * @return a Map of all TrafficLight, TrafficLightDecorator pairs
     */
    public Map getTrafficLightsMap() {
        return trafficLights;
    }

}
```

```
package londonsw.controller;


import londonsw.model.simulation.components.Lane;
import londonsw.model.simulation.components.vehicles.Vehicle;
import londonsw.view.simulation.VehicleGUIDecorator;


import java.util.ArrayList;
import java.util.HashMap;
import java.util.Map;

/**
 * This is the controller for all vehicle movement. It keeps track of all vehicl
es and their decorators. It also
 * has the methods that facilitates vehicle movement in the model and in the map
.
 */
public class VehicleController {

    private static Map<Vehicle, VehicleGUIDecorator> vehiclesAndDecorators = new
 HashMap<>();
    private static ArrayList<Vehicle> allVehicles = new ArrayList<>();

    /**
     * Register a car to a specific CarGuiDecorator so we can retrieve it and dr
aw the decorator for
     * for that car. This replaces the need to pass the CarGuiDecorator as a par
ameter. This also adds
     * the vehicle to an ArrayList, only to keep track of all cars in the system
 and nothing more.
     *
     * @param vehicle   an instance of a Vehicle type
     * @param decorator the CarGuiDecorator for that specific vehicle
     */
    public static void addVehicleAndDecoratorPair(Vehicle vehicle, VehicleGUIDec
orator decorator) {
        vehiclesAndDecorators.put(vehicle, decorator);
        allVehicles.add(vehicle);
    }

    /**
     * Removes the vehicle instance from the list of all vehicles and the map of
 all vehicle,decorator pairs
     * @param v the vehicle to remove
     */
    public static void removeFromListAndMap(Vehicle v) {
        allVehicles.remove(v);
        vehiclesAndDecorators.remove(v);
    }

    /**
     * Gets all the vehicles in the system
     * @return ArrayList with all vehicles in the system
     */
    public static ArrayList<Vehicle> getVehicleList(){
        return allVehicles;
    }
```

```java
    /**
     * Given an index in the array, this removes the vehicle from existence.
     * @param index the index in the list allVehicles that the vehicle occupies
     */
    public static void removeVehicle(int index) {
        try {
            Vehicle v = allVehicles.get(index);
            VehicleGUIDecorator decorator = vehiclesAndDecorators.get(v);
            decorator.getPane().getChildren().remove(decorator.getRectangle());
            v.setVehicleState(3);
            v.unsubscribe();
            Lane currLane = v.getCurrentLane();
            int currCell = v.getCurrentCell();
            currLane.setCell(null, currCell);
            allVehicles.remove(index);
            vehiclesAndDecorators.remove(v);
            v = null;
        } catch (Exception e) {
            e.printStackTrace();
        }
    }

    /**
     * Gets the total time spent standing for all vehicles in the system.
     * @return the total time spent standing by all vehicles in the system
     */
    public static int getTotalTimeSpentStanding() {
        int sum = 0;
        for(Vehicle v : allVehicles) {
            sum += v.getTimeSpentStanding();
        }
        return sum;
    }

    /**
     * Gets the total times ticked by all vehicles in the system. This is used i
n the calculation of
     * average time spent standing in the system.
     * @return
     */
    public static int getTotalTimesTicked() {
        int sum = 0;
        for(Vehicle v : allVehicles) {
            sum += v.getTimesTicked();
        }
        return sum;
    }

    /**
     * Retrieve the VehicleGGUIDecorator for the vehicle, for operations that ha
ppen outside this class
     *
     * @param vehicle the Vehicle to retrieve the decorator for
     * @return CarGuiDecorator instance associated with that specific Vehicle
     */
    public static VehicleGUIDecorator getDecoratorForVehicle(Vehicle vehicle) {
        return vehiclesAndDecorators.get(vehicle);
    }
    /**
     * This is the method that gets called by the Vehicle (in the model) when th
e ticker ticks. This controller
     * handles the rest of the moving.
     *
     * @param v    the Vehicle that notified that it should move
     * @param step how far the vehicle should move
     * @throws Exception
     */
    public static void moveOnTick(Vehicle v, int step) throws Exception {
        VehicleGUIDecorator decorator = vehiclesAndDecorators.get(v);
        moveVehicle(decorator, step);
    }

    /**
     * Moves the vehicle in the model and in the GUI
     * @param vehicleGUIDecorator the GUI decorator for this vehicle
     * @param step how many slots to move
     * @throws Exception
     */
    public static void moveVehicle(VehicleGUIDecorator vehicleGUIDecorator, int
step) throws Exception {

        int move = 0;

        vehicleGUIDecorator.setPreviousLane(vehicleGUIDecorator.getCurrentLane()
);
        vehicleGUIDecorator.setPreviousCoordinate(vehicleGUIDecorator.getCurrent
Coordinate());

        // Vehicle is at an intersection
        if (vehicleGUIDecorator.getCurrentCoordinate().equals(vehicleGUIDecorato
r.getCurrentLane().getExit())) {
            //only read when intersection is available
            vehicleGUIDecorator.readTrafficLight();

            if (vehicleGUIDecorator.getVehicleState() == 1) { // if vehicle was
moving
                // get next lane available to move to
                Lane l = vehicleGUIDecorator.chooseLane();

                vehicleGUIDecorator.setVehicleState(2); // set vehicle’s state t
o "in intersection"
                move = vehicleGUIDecorator.vehicleTurn(l); // move the vehicle i
n the model and get a result int
            }
        } else {
            if (vehicleGUIDecorator.getVehicleState() != 0) { // if not at inter
section, and wasn’t stopped, move forward
                move = vehicleGUIDecorator.moveVehicle(step);
            }
        }

        if(move == 0) {
            Vehicle thisVehicle = vehicleGUIDecorator.getVehicle();
            thisVehicle.incrementTimeSpentStanding();
        }

        if (vehicleGUIDecorator.getVehicleState() == 3) { //vehicle is deleted j
ust move to next space
            vehicleGUIDecorator.moveVehicleGUI(move, vehicleGUIDecorator.getVehi
cleState());
        }
        else if(move>0 && vehicleGUIDecorator.getVehicleState()!=0) { // move th
e vehicle in the GUI
            vehicleGUIDecorator.moveVehicleGUI(move, vehicleGUIDecorator.getVehi
cleState());
        }
    }
}
```

```
package londonsw.model.simulation;

import londonsw.model.simulation.components.TrafficLight;
import londonsw.model.simulation.components.vehicles.Vehicle;
import rx.Subscriber;

import java.io.File;
import java.io.IOException;
import java.util.ArrayList;
import java.util.logging.FileHandler;
import java.util.logging.Logger;
import java.util.logging.SimpleFormatter;


 /**
 * Created by felix on 18/03/2016.
  * Logs what is happening in the system for every tick.
 */

public class Log extends Subscriber<Long> {

     private String fileName;
     private final String LOG_DIR = "./logs/";
     private String filePath;

     /**
      * Creates a log with the given file name to log what is happening in the s
ystem. It will be stored in the
      * directory LOG_DIR.
      * @param fileName the file name for the log
      */
     public Log(String fileName) {
         this.fileName = fileName;

         File directory = new File(LOG_DIR);
         if(!directory.exists()) {
             directory.mkdir();
         }

         filePath = LOG_DIR + fileName + ".log";
         File logFile = new File(filePath);
         if(!logFile.exists()) {
             try {
                 logFile.createNewFile();
             } catch (IOException e) {
                 e.printStackTrace();
             }
         }

         Ticker.subscribe(this);
     }

     /**
      * Generates log information for that Ticker tick
      * @param aLong current time in the system
      */
     private void generate(long aLong) {

         ArrayList al = Ticker.getSubscribers();
```

```
        Logger logger = Logger.getLogger("SIMULATION");

        FileHandler fh;

        try {

            StringBuilder sb = new StringBuilder();

            sb.append("TICK!: " + aLong);
            sb.append(System.lineSeparator());

            for (Object o : al) {
                if (o instanceof Vehicle) {

                    Vehicle vLog = (Vehicle) o;

                    sb.append(System.lineSeparator());
                    sb.append("---------VEHICLE---------");
                    sb.append(System.lineSeparator());
                    sb.append("ID: " + vLog.getId());
                    sb.append(System.lineSeparator());
                    sb.append("CURRENT LANE ID: " + vLog.getCurrentLane().getId(
));
                    sb.append(System.lineSeparator());
                    sb.append("CURRENT COORDINATES: " + vLog.getCurrentCoordina
te().getX() + "," + vLog.getCurrentCoordinate().getY());
                    sb.append(System.lineSeparator());

                    if (vLog.getPreviousLane() != null) {
                        sb.append("PREVIOUS LANE ID: " + vLog.getPreviousLane().
getId());
                        sb.append(System.lineSeparator());
                        sb.append("PREVIOUS LANE COORDINATES: " + vLog.getPrevi
ousCoordinate().getX() + "," + vLog.getCurrentCoordinate().getY());
                        sb.append(System.lineSeparator());
                    }

                    sb.append("CURRENT CELL: " + vLog.getCurrentCell());
                    sb.append(System.lineSeparator());
                    sb.append("BEHAVIOUR: " + vLog.getVehicleBehavior());
                    sb.append(System.lineSeparator());
                    sb.append("PRIORITY: " + vLog.getVehiclePriority());
                    sb.append(System.lineSeparator());
                    sb.append("STATE: " + vLog.getVehicleState());
                    sb.append(System.lineSeparator());
                    sb.append("SUBSCRIBED: " + (vLog.isUnsubscribed()==false?"Y
ES":"NO"));


                } else if (o instanceof TrafficLight) {
                    TrafficLight tLog = (TrafficLight) o;
                    sb.append(System.lineSeparator());
                    sb.append("------TRAFFIC LIGHT------");
                    sb.append(System.lineSeparator());
                    sb.append("ID: " + tLog.getId());
                    sb.append(System.lineSeparator());
                    sb.append("DURATION: " + tLog.getDuration());
                    sb.append(System.lineSeparator());
                    sb.append("STATE: " + tLog.getState());
                }
            }

            sb.append(System.lineSeparator());
            sb.append("===================================================================
=");

            fh = new FileHandler(filePath,true);

            logger.addHandler(fh);
            SimpleFormatter formatter = new SimpleFormatter();
            fh.setFormatter(formatter);
            logger.setUseParentHandlers(false);
            logger.info(sb.toString());
            fh.close();

        } catch (SecurityException e) {
            e.printStackTrace();
        } catch (IOException e) {
            e.printStackTrace();
        }
    }

    @Override
    public void onCompleted() {  }

    /**
     * If there’s some error with the ticker and this subscriber, this method w
ould call.
     * Left not implemented on purpose
     * @param throwable
     */
    @Override
    public void onError(Throwable throwable) {    }

    /**
     * Called on Ticker tick, will generated a log entry for that tick
     * @param aLong current time in the sytem
     */
    @Override
    public void onNext(Long aLong) {
        generate(aLong);
    }
}
```

```java
package londonsw.model.simulation;

import londonsw.controller.TrafficLightController;
import londonsw.model.simulation.components.*;
import londonsw.view.simulation.IntersectionDecorator;
import londonsw.view.simulation.TrafficLightDecorator;

import java.io.*;
import java.util.ArrayList;
import java.util.Collections;
import java.util.HashMap;
import java.util.Random;

/**
 * This is the graph structure that our map holds (Roads and Intersections)
 */
public class Map implements Serializable {
    private static final long serialVersionUID = −1932129809569954013L;
    private ArrayList<Road> roads;
    private ArrayList<Intersection> intersections;
    private MapGrid grid;
    private final static String MAP_DIR = "./maps/";


    /**
     * Creates an empty map with no roads or intersections
     *
     * @param width width of the map
     * @param height height of the map
     */
    public Map(int width, int height) {
        roads = new ArrayList<Road>();
        intersections = new ArrayList<Intersection>();
        grid = new MapGrid(width,height);
    }

    /**
     * Gets the width of the map
     *
     * @return integer representing width of the map
     */
    public int getWidth() {
        return grid.getWidth();
    }

    /**
     * Gets the height of the map
     *
     * @return integer representing the height of the map
     */
    public int getHeight() {
        return grid.getHeight();
    }

    /**
     * Gets all the roads currently in the map
     * @return ArrayList of all Roads in the map
     */
    public ArrayList<Road> getRoads() {
        return roads;
    }

    /**
     * Gets a random road from the Map
     * @return a random Road instance from the current map
     */
    public Road getRandomRoad() {
        ArrayList<Road> roads = getRoads();
        Road road = null;
        Random randomRoad = new Random();

        if(roads.size() > 0) {
            int roadSize = randomRoad.nextInt(this.getRoads().size());
            road = roads.get(roadSize);
        }

        return road;
    }

    /**
     * Gets a random lane from the Map
     * @return a random Lane instance from the current Map
     */
    public Lane getRandomLane() {
        Road road = getRandomRoad();
        Lane lane = null;

        if (road != null) {
            Random randomLane = new Random();
            int numberLanes = road.getNumberLanes();

            if (numberLanes > 0) {
                int laneSize = randomLane.nextInt(road.getNumberLanes());
                lane = road.getLanes().get(laneSize);
                while (lane.getState() != 1) { // if road is disabled, choose a
new one
                    road = getRandomRoad();
                    lane = road.getLanes().get(randomLane.nextInt(road.getNumber
Lanes()));
                }
            }
        }

        return lane;
    }

    /**
     * Gets a random cell from a random Lane from the system, which is an int. A
 vehicle can go in this cell.
     * @return index of random cell from a random Lane in the Map
     */
    public int getRandomCell(){
        Random randomCell = new Random();
        Lane randomLane = getRandomLane();
        return randomCell.nextInt(randomLane.getLength());
    }

    /**
```

```
     * If you have a list of roads already, set the roads to the map
     * @param roads an ArrayList of valid Road instances
     */
    public void setRoads(ArrayList<Road> roads) {
        this.roads = roads;
        for(Road r : roads)
            grid.addComponent(r);
    }

    /**
     * Gets all the intersections currently in the map
     * @return ArrayList of all intersections in the map
     */
    public ArrayList<Intersection> getIntersections() {
        return intersections;
    }

    /**
     * If you have a list of intersections already, set the intersections to the
 map
     * @param intersections
     */
    public void setIntersections(ArrayList<Intersection> intersections) {
        this.intersections = intersections;
        for(Intersection i : intersections)
            grid.addComponent(i);
    }

    /**
     * Gets the underlying MapGrid of the Map and returns it
     * @return the actual MapGrid of this map
     */
    public MapGrid getGrid() {
        return grid;
    }

    /**
     * If you have a valid MapGrid grid, set it as the grid to this Map
     * @return valid instance of MapGrid
     */
    public void setGrid(MapGrid grid) {
        this.grid = grid;
    }

    /**
     * Adds a brand new road to this map.
     * @param r valid Road instance to put into the Map
     */
    public void addRoad(Road r) {
        roads.add(r);
        grid.addComponent(r);
    }

    public Component getAtLocation(Coordinate c) {
        int x = c.getX();
        int y = c.getY();
        return grid.get(x,y);
    }
    /**
     * Adds a brand new intersection to this map
     * @param i valid Intersection instance to put into the Map
     */
    public void addIntersection(Intersection i) {
        intersections.add(i);
        grid.addComponent(i);
    }

    /**
     * Removes the map Component at the given coordinate (only deletes it from t
he model, not the view)
     * @param c the coordinate where to delete the Map component
     */
    public void clearCell(Coordinate c) {
        int x = c.getX();
        int y = c.getY();
        grid.clearCell(x, y);
    }

    /**
     * Saves the map to the disk. Given a file name, it saves the map into MAP_D
IR with that file name
     * @param fileName the file name for saving the map
     */
    public void saveMap(String fileName)
    {
        try
        {
            File directory = new File(MAP_DIR);
            if(!directory.exists()) {
                directory.mkdir();
            }

            String path = MAP_DIR + fileName;

            File file = new File(path);
            if(!file.exists()) {
                file.createNewFile();
            }

            // save the map
            FileOutputStream fileOut = new FileOutputStream(path);
            ObjectOutputStream out = new ObjectOutputStream(fileOut);
            out.writeObject(this);
            out.close();
            fileOut.close();
        }catch(IOException i)
        {
            i.printStackTrace();
        }
    }

    /**
     * Loads a map from the disk with the given file name. It unserializes it an
d returns an instance of a Map. This
     * method is static so it can be called without any instances of a Map.
     * @param fileName the name of the map file to open (extension included)
     * @return an instance of a loaded Map that was opened from the disk
     */
    public static Map loadMap(String fileName) {
        Map map = null;

        try {
            // open the Map
            FileInputStream fileIn = new FileInputStream(fileName);
            ObjectInputStream in = new ObjectInputStream(fileIn);
            map = (Map) in.readObject();
            in.close();
            fileIn.close();

            /*
             * Each intersection has 4 traffic lights, for each traffic light:
             *      - subscribe to the ticker
             *      - create a new Decorator
             * For each intersection:
             *      - create a new IntersectionDecorator
             *      - link each new TrafficLightDecorator to the corresponding f
ield in the IntersectionDecorator
             * */
            for(Intersection i : map.getIntersections()) {
                i.subscribeToTicker();
                IntersectionDecorator decorator = new IntersectionDecorator(i);
                TrafficLight north = i.getNorthTrafficLight();
                TrafficLight south = i.getSouthTrafficLight();
                TrafficLight east = i.getEastTrafficLight();
                TrafficLight west = i.getWestTrafficLight();
                if(north != null) {
                    north.subscribeToTicker();
                    TrafficLightDecorator dec = TrafficLightController.getInstan
ce().createNewDecorator(north);
                    decorator.setNorthTrafficLightDecorator(dec);
                }
                if(south != null) {
                    south.subscribeToTicker();
                    TrafficLightDecorator dec = TrafficLightController.getInstan
ce().createNewDecorator(south);
                    decorator.setSouthTrafficLightDecorator(dec);
                }
                if(east != null) {
                    east.subscribeToTicker();
                    TrafficLightDecorator dec = TrafficLightController.getInstan
ce().createNewDecorator(east);
                    decorator.setEastTrafficLightDecorator(dec);
                }
                if(west != null) {
                    west.subscribeToTicker();
                    TrafficLightDecorator dec = TrafficLightController.getInstan
ce().createNewDecorator(west);
                    decorator.setWestTrafficLightDecorator(dec);
                }
            }

            long duration = TrafficLightController.getInstance().getDurationLeng
th();
            TrafficLightController.getInstance().setTrafficLightDuration(duratio
n);
            TrafficLightController.getInstance().setLightsToEnabled();
        } catch(IOException i) {
            System.out.println("IO Exception");
            i.printStackTrace();
        } catch (ClassNotFoundException e) {
            System.out.println("Did not find object");
            e.printStackTrace();
        }

        return map;
    }

    /**
     * For debug only. Prints the map layout to the console.
     */
    public void printMapGrid() {
        Component[][] grid = this.getGrid().getGrid();
        int width = this.getGrid().getWidth();
        int height = this.getGrid().getHeight();
        for(int i = 0; i < height; i++) {
            for(int j = 0; j < width; j++) {
                Component current = grid[i][j];
                if(current instanceof Road)
                    System.out.print("R ");
                else if(current instanceof Intersection)
                    System.out.print("I ");
                else
                    System.out.print("- ");
            }
            System.out.println();
        }
        System.out.println();
    }
}
```

```
package londonsw.model.simulation;

import londonsw.model.simulation.components.*;

import java.io.Serializable;
import java.lang.reflect.Array;
import java.util.ArrayList;

/**
 * This class is the underlying structure of our Map. It is a 2D−array of map Co
mponents,
 * each Component being something that you would want to be displayed on the map
, such as
 * a Road or Intersection.
 */
public class MapGrid implements Serializable, IMapGrid {

    private static final long serialVersionUID = −8256761045077358688L;
    private int width;
    private int height;
    private Component[][] grid;
    private ArrayList<Component> allComponents;

    /**
     * Creates a brand new MapGrid instance to be part of a Map
     * @param width width of the Map that this will be part of
     * @param height height of the Map that this will be part of
     */
    public MapGrid(int width, int height) {
        this.width = width;
        this.height = height;
        grid = new Component[height][width];
        allComponents = new ArrayList<Component>();
    }

    /**
     * Returns the actual 2D−array of Components
     * @return 2D−array array of Components signifying the layout of the Map
     */
    public Component[][] getGrid() {
        return grid;
    }

    /**
     * Gets the width of the grid
     * @return width of the grid
     */
    public int getWidth() {
        return width;
    }

    /**
     * Gets the height of the grid
     * @return height of the grid
     */
    public int getHeight() {
        return height;
    }
    /**
     * Gets all Components from the MapGrid
     * @return an ArrayList of all components in the Map
     */
    public ArrayList<Component> getAllComponents() { return allComponents; }

    /**
     * Gets a Component from the MapGrid at the given (x, y) location
     * @param x the x coordinate of the requested Component
     * @param y the y coordinate of the requested Component
     * @return a Component at the location (x, y), if there is nothing there, nu
ll is returned
     */
    public Component get(int x, int y) {
        return grid[y][x];
    }

    /**
     * Empties the cell at the given (x, y) location
     * @param x the x−coordinate where to clear the
     * @param y
     */
    public void clearCell(int x, int y) {
        grid[y][x] = null;
    }

    /**
     * Adds a Component to the map grid structure
     * @param c the Component to be added
     * @return true if successfully added, false otherwise
     */
    @SuppressWarnings("Duplicates")
    public boolean addComponent(Component c) {
        if(c instanceof Intersection) {
            Intersection i = (Intersection) c;
            Coordinate coord = i.getLocation();
            grid[coord.getY()][coord.getX()] = i;
            allComponents.add(i);
            return true;
        }
        else if(c instanceof Road) {
            Road road = (Road) c;
            Coordinate start = road.getStartLocation();
            Coordinate end = road.getEndLocation();
            int startX = start.getX();
            int startY = start.getY();
            int endX = end.getX();
            int endY = end.getY();

            if(road.runsVertically()) { // road runs vertically
                if(startY <= endY) { // start coordinate is north of end coordin
ate
                    for(int i = startY; i <= endY; i++) {
                        grid[i][startX] = road;
                    }
                    allComponents.add(road);
                    return true;
                }
                else { // start coordinate is south of end coordinate
```

```
                    for(int i = endY; i <= startY; i++) {
                        grid[i][startX] = road;
                    }
                    allComponents.add(road);
                    return true;
                }
            }
            else { // road runs horizontally
                if(startX <= endX) { // start coordinate is west of end coordina
te
                    for(int i = startX; i <= endX; i++) {
                        grid[startY][i] = road;
                    }
                    allComponents.add(road);
                    return true;
                }
                else {
                    for(int i = endX; i <= startX; i++) { // start coordinate is
 east of end coordinate
                        grid[startY][i] = road;
                    }
                    allComponents.add(road);
                    return true;
                }
            }
        }
        else
            return false;
    }

}
```

```java
package londonsw.model.simulation;

/**
 * This is the class that keeps time for our simulation
 *
 * This uses RxJava’s Observer and Subscriber to pass events to the classes that
 want messages from the
 * ticker. This also uses RxJavaFx to make sure that the GUI events are running
on the JavaFX thread scheduler.
 */

import rx.Observable;
import rx.Subscriber;
import rx.schedulers.JavaFxScheduler;
import rx.subjects.PublishSubject;

import java.util.ArrayList;
import java.util.concurrent.TimeUnit;

public class Ticker {

    private static ArrayList<Subscriber<Long>> subscribers = new ArrayList<Subsc
riber<Long>>();;

    private static long TICK_INTERVAL = 1000;

    private static Ticker instance;

    private static Observable<Long> tickerObservable;

    private static PublishSubject stop = PublishSubject.create();


    protected Ticker() { }

    /**
     * Singleton of the Ticker class, prevents having more than 1 ticker in the
system. Creates a new
     * Ticker if one does not yet exist, otherwise gives the instance
     * @return
     */
    public static Ticker getInstance() {
        if(instance == null) {
            instance = new Ticker();
        }
        return instance;
    }

    /**
     * Starts the ticker with the tick interval
     */
    public static void start() {
        tickerObservable = Observable.interval(TICK_INTERVAL, TimeUnit.MILLISECO
NDS);
    }

    /**
     * Adds a subscriber to the ticker. Any class that extends Subscriber can su
bscribe to the ticker. This
```

```
     * also adds the subscriber to an arraylist of subscribers just to keep trac
k of them all.
     * @param sub the new subscriber to the ticker
     */
    public static void subscribe(Subscriber<Long> sub) {
        if(tickerObservable!=null) {
            tickerObservable.takeUntil(stop).observeOn(JavaFxScheduler.getInstan
ce()).subscribe(sub);
            subscribers.add(sub);
        }
    }

    /**
     * Get the list of all subscribers of this ticker, which can include Vehicle
s and TrafficLights
     * @return ArrayList of all subscribers of the ticker
     */
    public static ArrayList<Subscriber<Long>> getSubscribers() {
        return subscribers;
    }

    /**
     * Get the length of the current tick interval
     * @return length of the current tick interval
     */
    public static long getTickInterval() { return TICK_INTERVAL; }

    /**
     * Change the length of a tick interval.
     * @param interval length of new interval
     */
    public static void setTickInterval(long interval) { TICK_INTERVAL = interval
; }


    /**
     * Ends the ticker. All subscribers must unsubscribe and a "stop" call is ex
plicitly called, just in case.
     */
    public static void end() {
        for(Subscriber s : subscribers)
            s.unsubscribe();
        stop.onNext(null);
    }

}
```

```
package londonsw.model.simulation.components;

/**
 * This interface is to have a common denominator between things that can be add
ed to a Map
 * Currently, there are two types of Components, Intersections and Roads
 */
public interface Component {
 // intersection or road
}
```

```
package londonsw.model.simulation.components;

import java.io.Serializable;

/**
 * The Coordinate class represents an (x, y) pair of integers that signify a loc
ation in the map
 * Coordinates are also used for doing calculations and translations for movemen
t of vehicles
 * A coordinate at the top-left of a map is (0,0)
 */
public class Coordinate implements Serializable {

    private static final long serialVersionUID = 2522457951482787739L;
    private int x, y;

    /**
     *
     * @param x takes the value of the x region/axis
     * @param y takes the value of the y region
     */
    public Coordinate(int x, int y) {
        this.x = x;
        this.y = y;
    }

    /**
     * Sets the y coordinate of this instance
     * @param y int of the y coordinate
     */
    public void setY(int y) {
        this.y = y;
    }

    /**
     * Sets the x coordinate of this instance
     * @param x int of the x coordinate
     */
    public void setX(int x) {
        this.x = x;
    }

    /**
     * Gets the x-coordinate of this instance
     * @return int of the x coordinate
     */
    public int getX() {
        return x;
    }

    /**
     * Gets the y-coordinate of this instance
     * @return int of the y coordinate
     */
    public int getY() {
        return y;
    }

    /**
```

```
     * Checks if two coordinates are equal
     * @param obj coordinate to be compared with
     * @return true if the coordinates are the same, false otherwise
     */
    public boolean equals(Object obj) {
        Coordinate other = (Coordinate)obj;
        return (x == other.getX()) && (y == other.getY());
    }

    /**
     * Adds 2 coordinates and returns their sum
     * @param a first coordinate to add
     * @param b second coordinate to add
     * @return the sum of the two coordinates’ x’s and y’s as a Coordinate insta
nce
     */
    public static Coordinate add(Coordinate a, Coordinate b) {
        return new Coordinate(a.getX()+b.getX(), a.getY()+b.getY());
    }

    /**
     * Subtracts 2 coordinates and returns their difference
     * @param a coordinate to subtract from
     * @param b coordinate to subtract
     * @return the difference of the two coordinates’ x’s and y’s as a Coordinat
e instance
     */
    public static Coordinate substract(Coordinate a, Coordinate b) {
        return new Coordinate(a.getX()−b.getX(), a.getY()−b.getY());
    }

    /**
     * Formats the coordinate for console output
     * @return the coordinate formatted as follows: (x, y)
     */
    public String toString() {
        return "(" + x + "," + y + ")";
    }

    /**
     * Adds a step to the coordinate based on map direction. i.e if the map dire
ction is eastwards,
     * and a specified coordinate is (2,1), calling addStep method returns a new
 coordinate with dimensions (2,1)
     * @param mapDirection i.e directions north,south, east or west
     * @return sum, returns a new valid coordinate with a step added to it
     */
    public Coordinate addStep(MapDirection mapDirection) {
        Coordinate sum = new Coordinate(−1,−1);

        switch (mapDirection) {
            case NORTH:
                sum.setY(this.getY() − 1);
                sum.setX(this.getX());
                break;
            case SOUTH:
                sum.setY(this.getY() + 1);
                sum.setX(this.getX());
                break;
            case EAST:
                sum.setX(this.getX() + 1);
                sum.setY(this.getY());
                break;
            case WEST:
                sum.setX(this.getX() − 1);
                sum.setY(this.getY());
                break;
        }

        return sum;
    }

}
```

```java
package londonsw.model.simulation.components;

/**
 * Created by felix on 25/02/2016.
 */
public interface IMapGrid {

    Component[][] getGrid();

    int getWidth();

    int getHeight();

    boolean addComponent(Component component);

}
```

```
package londonsw.model.simulation.components;

import java.util.ArrayList;

/**
 * Created by felix on 23/02/2016.
 */
public interface IRoad {
    ArrayList<Lane> getLanes();
    void addLane(Lane lane);
    Lane getLaneAtIndex(int index);
    Coordinate getEndLocation();
    int getNumberLanes();
    Intersection getIntersection();
    void setIntersection(Intersection intersection);
    int getLength();
    boolean runsVertically();
}
```

```java
package londonsw.model.simulation.components;

/**
 * Interface ITrafficLight
 */
public interface ITrafficLight {

    /**
     * Methods....
     */
    public void nextState();
    public void change(int no);
    public void setDuration(long duration);
    public long getDuration();
}
```

```
package londonsw.model.simulation.components;

import londonsw.controller.IntersectionController;
import londonsw.model.simulation.components.vehicles.Vehicle;
import rx.Subscriber;
import londonsw.model.simulation.Ticker;

import java.io.Serializable;
import java.util.ArrayList;
import java.util.Random;


/**
 * This class is our "node" in our directed graph
 * It will hold anywhere between 1 and 4 traffic lights
 * It will connect anywhere between 2 and 4 roads
 * Each will have a location in the map
 */

/* the traffic light belongs to the road
 * in each intersection, a car can choose(maybe randomly) Which road he can ente
r based on the array IntersectionRoad
 */


public class Intersection extends Subscriber<Long> implements Component, Serializa
ble {

    private static final long serialVersionUID = -2621352799268337492L;
    private Road northRoad;
    private Road southRoad;
    private Road eastRoad;
    private Road westRoad;

    private TrafficLight northTrafficLight;
    private TrafficLight southTrafficLight;
    private TrafficLight eastTrafficLight;
    private TrafficLight westTrafficLight;
    private ArrayList<TrafficLight> allLights;
    private int id;
    private Coordinate location;
    private static  int counter=0;


    /**
     * Creats
     * @param location
     */
    public Intersection(Coordinate location){
        this.northRoad = null;
        this.southRoad = null;
        this.eastRoad = null;
        this.westRoad = null;
        this.location = location;
        this.northTrafficLight = null;
        this.southTrafficLight = null;
        this.eastTrafficLight = null;
        this.westTrafficLight = null;
        Ticker.subscribe(this);
        id=++counter;
    }

    /* getters */
    public TrafficLight getNorthTrafficLight() {
        return northTrafficLight;
    }
    public TrafficLight getSouthTrafficLight() {
        return southTrafficLight;
    }
    public TrafficLight getEastTrafficLight() {
        return eastTrafficLight;
    }
    public TrafficLight getWestTrafficLight() {
        return westTrafficLight;
    }
    public Road getNorthRoad() {
        return northRoad;
    }
    public Road getEastRoad() {
        return eastRoad;
    }
    public Road getSouthRoad() {
        return southRoad;
    }
    public Road getWestRoad() {
        return westRoad;
    }
    public Coordinate getLocation() {
        return location;
    }
    public int getId() {
        return id;
    }

    /* setters */
    public void setNorthTrafficLight(TrafficLight northTrafficLight) {
        this.northTrafficLight = northTrafficLight;
    }
    public void setSouthTrafficLight(TrafficLight southTrafficLight) {
        this.southTrafficLight = southTrafficLight;
    }
    public void setEastTrafficLight(TrafficLight eastTrafficLight) {
        this.eastTrafficLight = eastTrafficLight;
    }
    public void setWestTrafficLight(TrafficLight westTrafficLight) {
        this.westTrafficLight = westTrafficLight;
    }
    public void setLocation(Coordinate location) throws IntersectionSetupExcepti
on {
        this.location = location;
    }
    public void setIdIntersection(int id) {
        this.id = id;
    }

    /**
     * Subscribes this intersection to the Ticker. This is expecially useful whe
```

```
n loading maps from file!
     */
    public void subscribeToTicker() {
        Ticker.subscribe(this);
    }


    public void setNorthRoad(Road northRoad) throws Exception {
        if((this.location.getX() == northRoad.getEndLocation().getX()
                && (this.location.getY() - 1 == northRoad.getEndLocation().getY(
)
                ||  this.location.getY() - 1 == northRoad.getStartLocation().get
Y())))
        {
            this.northRoad = northRoad;
            for(int i=0; i<this.northRoad.getNumberLanes();i++){
                if(this.northRoad.getLaneAtIndex(i).getMovingDirection()==MapDir
ection.SOUTH)
                {
                    this.northRoad.getLaneAtIndex(i).setEndIntersection(this);
                }
            }
        }
        else
            throw new IntersectionSetupException("Road end location coordinates must match w
ith Intersection");
    }

    public void setSouthRoad(Road southRoad) throws Exception {
        if((this.location.getX()==southRoad.getEndLocation().getX()
                && (this.location.getY() + 1 == southRoad.getEndLocation().getY(
)
                || this.location.getY() + 1 == southRoad.getStartLocation().getY
())))
        {
            this.southRoad = southRoad;
            for(int i=0; i<this.southRoad.getNumberLanes();i++){
                if(this.southRoad.getLaneAtIndex(i).getMovingDirection()==MapDir
ection.NORTH)
                {
                    this.southRoad.getLaneAtIndex(i).setEndIntersection(this);
                }
            }

        }
        else
            throw new IntersectionSetupException("Road end location coordinates must match w
ith Intersection");
    }

    public void setEastRoad(Road eastRoad) throws Exception {
        if (this.location.getY() == eastRoad.getEndLocation().getY()
                && (this.location.getX() + 1  == eastRoad.getEndLocation().getX(
)
                || this.location.getX() + 1 == eastRoad.getStartLocation().getX(
))) {
            this.eastRoad = eastRoad;
            for(int i=0; i<this.eastRoad.getNumberLanes();i++){
                if(this.eastRoad.getLaneAtIndex(i).getMovingDirection()==MapDire
ction.WEST)
                {
                    this.eastRoad.getLaneAtIndex(i).setEndIntersection(this);
                }
            }

        } else
            throw new IntersectionSetupException("Road end location coordinates must match w
ith Intersection");
    }

    public void setWestRoad(Road westRoad) throws IntersectionSetupException {
        if ((this.location.getY()  == westRoad.getEndLocation().getY()
                && (this.location.getX() - 1 == westRoad.getEndLocation().getX()
                || this.location.getX() -1 == westRoad.getStartLocation().getX()
))) {
            this.westRoad = westRoad;
            for(int i=0; i<this.westRoad.getNumberLanes();i++){
                if(this.westRoad.getLaneAtIndex(i).getMovingDirection()==MapDire
ction.EAST)
                {
                    this.westRoad.getLaneAtIndex(i).setEndIntersection(this);
                }
            }

        } else
            throw new IntersectionSetupException("Road end location coordinates must match w
ith Intersection");
    }

    public void setDefaultTrafficLightsForRoads() {
        if(northRoad != null) {
            ArrayList<Lane> lanes = northRoad.getLanes();
            boolean hasSouthLane = false;
            for(Lane l : lanes) {
                if(l.getMovingDirection() == MapDirection.SOUTH) {
                    hasSouthLane = true;
                    break;
                }
            }
            if(hasSouthLane)
                northTrafficLight = new TrafficLight();
        }

        if(southRoad != null) {
            ArrayList<Lane> lanes = southRoad.getLanes();
            boolean hasNorthLane = false;
            for(Lane l : lanes) {
                if(l.getMovingDirection() == MapDirection.NORTH) {
                    hasNorthLane = true;
                    break;
                }
            }
            if(hasNorthLane)
                southTrafficLight = new TrafficLight();
        }
        if(eastRoad != null) {
            ArrayList<Lane> lanes = eastRoad.getLanes();
            boolean hasWestLane = false;
            for(Lane l : lanes) {
                if(l.getMovingDirection() == MapDirection.WEST) {
                    hasWestLane = true;
                    break;
                }
            }
            if(hasWestLane) {
                if (northRoad != null || southRoad != null) {
                    eastTrafficLight = new TrafficLight(LightColour.GREEN);
                } else
                    eastTrafficLight = new TrafficLight();
            }
        }
        if(westRoad != null) {
            ArrayList<Lane> lanes = westRoad.getLanes();
            boolean hasEastLane = false;
            for(Lane l : lanes) {
                if(l.getMovingDirection() == MapDirection.EAST) {
                    hasEastLane = true;
                    break;
                }
            }
            if(hasEastLane) {
                if (northRoad != null || southRoad != null)
                    westTrafficLight = new TrafficLight(LightColour.GREEN);
                else
                    westTrafficLight = new TrafficLight();
            }
        }
    }


    /**
     * generate a list of 4 items form 1 to 4
     * these items are placed in the array randomly
     * @return list of integer in type of ArrayList
     */
    public static ArrayList<Integer> generateRandom (){
        int size =4;
        ArrayList<Integer> list = new ArrayList<Integer>(size);
        ArrayList<Integer> l = new ArrayList<Integer>(size);

        for(int i = 1; i <= size; i++) {
            list.add(i);
        }Random rand = new Random();
        while(list.size() > 0) {
            int index = rand.nextInt(list.size());
            l.add(list.get(index));
           // System.out.println("Selected: "+list.remove(index));
            list.remove(index);
        }

        return l;

    }


    /**
     * intersection gives each vehicle on it a priority to turn first
     * first it checks :
     * 1. if there is a road connected to it.
     * 2. if in the road there is a lane which its direction to this intersectio
n
     * 3. if there is a vehicle at the last cell in this lane, which is this int
ersection
     * if these conditions are obtained , then the intersection gives this vehic
le a priority to turn
     * and put these vehicle in arrayList .
     * @param randomPriority a list 4 items form 1 to 4, arranged randomly in th
e array list
     * @return vehicleInIntersection an arrayList in type of integer , which con
tains all vehicles which
     * has priority to turn
     * @throws
     */
    public ArrayList<Vehicle> giveVehiclePriorities (ArrayList<Integer>  randomP
riority) throws Exception {

      // ArrayList<Integer>  randomPriority = (ArrayList<Integer>)this.generate
Random(4).clone();
        ArrayList<Vehicle> vehicleInIntersection= new ArrayList<>() ;

        if (this.getNorthRoad() != null) {
            for (int i = 0; i < this.getNorthRoad().getNumberLanes(); i++) {
                if ((this.getNorthRoad().getLaneAtIndex(i).getMovingDirection()
== MapDirection.SOUTH)) {
                    if ((this.getNorthRoad().getLaneAtIndex(i).getVehicleInInter
section() != null)) {
                        if(this.getNorthTrafficLight()!= null)
                            this.getNorthRoad().getLaneAtIndex(i).getVehicleInIn
tersection().setVehicleTrafficLight(this.getNorthTrafficLight());
                        this.getNorthRoad().getLaneAtIndex(i).getVehicleInInters
ection().setVehiclePriorityToTurn(randomPriority.get(0));
                        vehicleInIntersection.add( this.getNorthRoad().getLaneAt
Index(i).getVehicleInIntersection());
                    }
                }
            }
        }

        if (this.getSouthRoad() != null) {
            for (int i = 0; i < this.getSouthRoad().getNumberLanes(); i++) {
                if ((this.getSouthRoad().getLaneAtIndex(i).getMovingDirection()
== MapDirection.NORTH)) {
                    if ((this.getSouthRoad().getLaneAtIndex(i).getVehicleInInter
section() != null)) {
                        if(this.getSouthTrafficLight()!= null)
                            this.getSouthRoad().getLaneAtIndex(i).getVehicleInIn
tersection().setVehicleTrafficLight(this.getSouthTrafficLight());
                        this.getSouthRoad().getLaneAtIndex(i).getVehicleInInters
ection().setVehiclePriorityToTurn(randomPriority.get(1));
                        vehicleInIntersection.add( this.getSouthRoad().getLaneAt
Index(i).getVehicleInIntersection());
                    }
                }
            }
        }
        if (this.getEastRoad() != null) {
            for (int i = 0; i < this.getEastRoad().getNumberLanes(); i++) {
                if ((this.getEastRoad().getLaneAtIndex(i).getMovingDirection() =
= MapDirection.WEST)) {
                    if ((this.getEastRoad().getLaneAtIndex(i).getVehicleInInters
ection() != null)) {
                        if(this.getEastTrafficLight()!= null)
                            this.getEastRoad().getLaneAtIndex(i).getVehicleInInt
ersection().setVehicleTrafficLight(this.getEastTrafficLight());
                        this.getEastRoad().getLaneAtIndex(i).getVehicleInInterse
ction().setVehiclePriorityToTurn(randomPriority.get(2));
                        vehicleInIntersection.add( this.getEastRoad().getLaneAtI
ndex(i).getVehicleInIntersection());
                    }
                }
            }
        }

        if (this.getWestRoad() != null) {
            for (int i = 0; i < this.getWestRoad().getNumberLanes(); i++) {
                if ((this.getWestRoad().getLaneAtIndex(i).getMovingDirection() =
= MapDirection.EAST)) {
                    if ((this.getWestRoad().getLaneAtIndex(i).getVehicleInInters
ection() != null)) {
                        if(this.getWestTrafficLight()!= null)
                            this.getWestRoad().getLaneAtIndex(i).getVehicleInInt
ersection().setVehicleTrafficLight(this.getWestTrafficLight());
                        this.getWestRoad().getLaneAtIndex(i).getVehicleInInterse
ction().setVehiclePriorityToTurn(randomPriority.get(3));
                        vehicleInIntersection.add( this.getWestRoad().getLaneAtI
ndex(i).getVehicleInIntersection());
                    }
                }
            }
        }
        return vehicleInIntersection;

    }

    /**
     * checks the vehicle with higher priority to turn
     * if a vehicle has a higher priority
     * it sets its priority to turn to 1 which means move
     * otherwise sets it to 0 which means stop
     * @param vehicles an array list in type of integer which contains all vehic
les which has priority to turn
     * @return
     * @throws Exception
     */
    public boolean vehicleTurnFirst (ArrayList<Vehicle> vehicles)throws Exceptio
n{
        int max=0;

       // for (int i=0; i<vehicles.size();i++)
       // {System.out.println("ID is: " + vehicles.get(i).getId()+ "  priority i
s : "+ vehicles.get(i).getVehiclePriorityToTurn());}


        if (vehicles != null) {
```

```
    for (int i = 0; i < vehicles.size(); i++) {
            if (max <= vehicles.get(i).getVehiclePriorityToTurn() ){
                if(vehicles.get(i).getVehicleTrafficLight()!= null){
                if(vehicles.get(i).getVehicleTrafficLight().getState()==LightCol
our.GREEN)
                max = vehicles.get(i).getVehiclePriorityToTurn();}
        else max = vehicles.get(i).getVehiclePriorityToTurn();}

    }


    for (int i = 0; i < vehicles.size(); i++) {
            if (vehicles.get(i).getVehiclePriorityToTurn() == max || vehicles.ge
t(i).getVehiclePriority()==5)
            {vehicles.get(i).setVehiclePriorityToTurn(1);}
        else vehicles.get(i).setVehiclePriorityToTurn(0);
    }
}

        return true;
    }


    /**
     * This is the method that gets called when the ticker terminates
     *  Left not implemented on purpose
     */
    @Override
    public void onCompleted() {

    }

    /**
     * If there’s some error with the ticker and this subscriber, this method wo
uld call.
     * Left not implemented on purpose
     * @param throwable
     */
    @Override
    public void onError(Throwable throwable) {

    }

    /**
     * This is like the onTick method. This is what intersection would do when t
he ticker ticks.
     * @param aLong this gives the current time in the system to the intersectio
n (although it is probably not required)
     */
    @Override
    public void onNext(Long aLong){
        try {

            IntersectionController.vehicleTurnFirst(this, this.giveVehiclePriori
ties(this.generateRandom()));
        } catch (Exception e) {
            e.printStackTrace();
        }
    }



}

class IntersectionSetupException extends Exception {
    public IntersectionSetupException() {
        super();
    }
    public IntersectionSetupException(String msg) {
        super();
    }
    public IntersectionSetupException(String msg, Throwable t) {
        super(msg, t);
    }
    public IntersectionSetupException(Throwable t) {
        super(t);
    }
}
```

```
package londonsw.model.simulation.components;
import londonsw.model.simulation.components.vehicles.Vehicle;

import java.io.Serializable;

/**
 * This class is where the vehicles actually move
 * This is based on the cell automaton model of simulation
 * Each lane is an "queue" and has a direction
 * Number slots in the lane will be based on the number of "cells" in the view t
he road/lane takes up
 */
public class Lane implements Serializable {

    private static final long serialVersionUID = 7899381124564682583L;
    private Vehicle[] lane;
    private int length;
    private Coordinate entry;
    private Coordinate exit;
    private MapDirection movingDirection;
    private Road road;
    private Intersection endIntersection;
    private int RoadIndex;
    private int state;
    private int id;
    private static  int counter=0;


    /**
     * Creates a lane and sets its first and last cell and it’s moving direction
     * and calculate the length of a lane and gives it a unique Id
     * stes the state to 1 which means a lane is enabled.
     * @param entry first cell in a lane in type of Coordinate
     * @param exit last cell in a lane un type of Coordinate
     * @param movingDirection the moving direction  of a lane in type of Map dir
ection
     * @throws NotALaneException
     */
    public Lane(Coordinate entry, Coordinate exit, MapDirection movingDirection)
 throws NotALaneException {
        this.entry = entry;
        this.exit = exit;
        this.movingDirection = movingDirection;
        length = this.getLaneLength();
        lane = new Vehicle[length];
        id=++counter;
        this.setState(1);
    }


    /**
     * Gets the vehicle in last cell in a lane
     * @return the vehicle in an intersection if there is any in type of vehicle
     * if there is no, it returns null
     * @throws Exception
     */
    public Vehicle getVehicleInIntersection() throws Exception {
        if (lane[length−1] != null)
            return lane[length−1];
        else
            return null;
    }

    /**
     * Gets a lane's state
     * 1 if a lane is enabled
     * 0 if it is disabled
     *
     * @return the state of a lane in type of integer
     */
    public int getState() {
        return state;
    }

    /**
     * Gets a unique ID for the lane
     * @return a lane's ID in type of integer
     */
    public int getId() {
        return id;
    }


    /**
     * Sets an ID to the lane
     * @param id is a unique Id for a lane in type of integer
     */
    public void setId(int id) {
        this.id = id;
    }

    /**
     * Sets a state of a lane
     * @param state is the state of a lane in type of integer
     *              where 1 is enabled  and 0 is disabled
     */
    public void setState(int state) {
        this.state = state;
    }


    /**
     * Gets the length of a lane,
     * and checks if it is a legal lane : which means the entry and exit coordin
ate of a lane must have
     * either same x's or y's
     *
     * @return the lane length in type od integer
     * @throws NotALaneException if the lane coordinates are not legal.
     */
    private int getLaneLength() throws NotALaneException {
        int aX = entry.getX();
        int aY = entry.getY();
        int bX = exit.getX();
        int bY = exit.getY();
        int length;

        if (aX == bX) {
```

```java
            length = Math.abs(aY − bY) + 1;
            return length;
        } else if (aY == bY) {
            length = Math.abs(aX − bX) + 1;
            return length;
        } else
            throw new NotALaneException("Not a lane. Coordinate x or y must match for both");
    }

    /**
     * Gets the length of a lane
     * @return the lane length in type of integer
     */
    public int getLength() {
        return length;
    }

    /**
     * Checks if a given cell is empty
     * @param cell is a cell in a lane in type of integer
     * @return the true if a cell is empty and false if not
     */
    public boolean isCellEmpty(int cell) {
        if (cell < 0 || cell > this.length)
            return false;

        if (lane[cell] == null)
            return true;
        return false;
    }

    /**
     * Checks if a lane is full
     * @return true if a lane is full, false otherwise
     */
    public boolean isFull ()
    {
        for (int i=0; i<this.getLength();i++)
        {if (this.isCellEmpty(i))
            return false;
        }
        return true;
    }

    /**
     * Gets the entry coordinate of a lane
     * @return the lane entry in type of coordinate
     */
    public Coordinate getEntry() {
        return entry;
    }

    /**
     * Gets the exit coordinate of a lane
     * @return the lane exit in type of coordinate
     */
    public Coordinate getExit() {
        return exit;
    }
    /**
     * Gets the moving direction of a lane
     * @return the lane moving direction in type of MapDirection
     */
    public MapDirection getMovingDirection() {
        return movingDirection;
    }

    /**
     * Gets the road that a lane is belongs to
     * @return the Road that lane in it in type of road
     */
    public Road getRoad() {return road; }

    /**
     * Sets the road that a alane belongs to
     * @param road to set it to a lane in type of road
     */
    public void setRoad(Road road) {this.road = road;}


    /**
     * Gets the end Intersection of a lane,
     * @return the lane End intersection in type of Intersection
     */
    public Intersection getEndIntersection() {
        return endIntersection;
    }

    /**
     * Sets the end intersection for a lane
     *
     * then sets the intersection to the
     * and checks if the intersection is in the right coordinates
     * and if it matches the correct lane direction
     * @param endIntersection is the intersection to set to the lane
     */
    public void setEndIntersection(Intersection endIntersection) {
        int x =endIntersection.getLocation().getX();
        int y =endIntersection.getLocation().getY();

        if ((this.getMovingDirection()==MapDirection.NORTH)&&(this.getExit().get
X()==x)&&(this.getExit().getY()==y+1) )
        {this.endIntersection = endIntersection;}

        else if ((this.getMovingDirection()==MapDirection.SOUTH)&&(this.getExit(
).getX()==x)&&(this.getExit().getY()==y−1) )
        {this.endIntersection = endIntersection;}

        else if((this.getMovingDirection()==MapDirection.EAST)&&(this.getExit().
getX()==x−1)&&(this.getExit().getY()==y) )
        {this.endIntersection = endIntersection;}

        else if((this.getMovingDirection()==MapDirection.WEST)&&(this.getExit().
getX()==x+1)&&(this.getExit().getY()==y) )
        {this.endIntersection = endIntersection;}

    }
    /**
     * @param v is a vehicle to set it to a lane
     * @param cell is a cell in a lane to set vehicle on it
     * @return true if a vehicle is setted
     * false if the cell is out of bound
     */
    public boolean setCell(Vehicle v, int cell) {
        if (cell < 0 || cell >= length)
            return false;

        lane[cell] = v;
        return true;
    }




    public int getRoadIndex() {
        return RoadIndex;
    }
    public Vehicle get(int i) {
        return lane[i];
    }
    public void setRoadIndex(int roadIndex) {
        RoadIndex = roadIndex;
    }

    public static boolean Rotate(Lane lane1, Lane lane2){
        if (lane1.getMovingDirection()==lane2.getMovingDirection()){
            return false;
        }
        return true;
    }
}

class NotALaneException extends Exception {
    public NotALaneException() { super(); }
    public NotALaneException(String msg) { super(msg); }
    public NotALaneException(String msg, Throwable t) { super(msg,t); }
    public NotALaneException(Throwable t) { super(t); }
}
```

```java
package londonsw.model.simulation.components;

/**
 * This enum represents the types of colors that a TrafficLight could have. The
system only uses RED and GREEN at the moment,
 * but in case YELLOW was to be added in the future, it is included here as well
.
 */
public enum LightColour {
    GREEN, YELLOW, RED
}
```

```
package londonsw.model.simulation.components;

/**
 * This enum is to represent different directions in the map, namely the 4 cardi
nal directions NORTH, SOUTH, EAST, AND WEST.
 */
public enum MapDirection {
    NORTH, SOUTH, EAST, WEST, ERROR
}
```

```
package londonsw.model.simulation.components;

import java.math.BigDecimal;

/**
 * This class represents how images will be resized to fit on the screen. Each i
mage in our system is 100x100, but they
 * need to be scaled down in order to be displayed properly. This is used throug
hout the system, for drawing the grid
 * squares, vehicles, and determining the location to where vehicles will move.
 */
public class ResizeFactor {

    private double resizeX;
    private double resizeY;

    /**
      * Creates a new ResizeFactor instance. There are two parameters, although o
nly one is used in most situations. This
      * is so that each square image maintains its aspect ratio. The typical rang
e for resize factors is from 0 < ResizeFactor < 1.
      * @param resizeX how much to resize the x direction by
      * @param resizeY how much to resize the y direction by
      */
    public ResizeFactor(double resizeX, double resizeY) {
        this.resizeX = resizeX;
        this.resizeY = resizeY;
    }

    /**
      * Gets the resize factor of the x-direction
      * @return resize factor of x
      */
    public double getResizeX() {
        return resizeX;
    }

    /**
      * Gets the resize factor of the y-direction
      * @return resize factor of y
      */
    public double getResizeY() {
        return resizeY;
    }

    /**
      * Dynamically determines the resize factor for a map. Given a map width and
 height, determine the best
      * resize factor so that the map best displays on the user’s display. It use
s the larger of the two dimensions
      * to determine the best fitting resize factor.
      * @param mapWidth width of the map to get a resize factor for
      * @param mapHeight height of the map to get a resize factor for
      * @return a ResizeFactor that is good for the given map dimensions
      */
    public static ResizeFactor getSuggestedResizeFactor(int mapWidth, int mapHei
ght) {
        int larger = mapHeight > mapWidth ? mapHeight : mapWidth;
        double rf = 1.0;
        if(larger < 10 || larger < 10) {
            rf = 1.0 / (mapHeight * 0.4);
        }
        else {
            rf = 1.0 / (larger * 0.2);
        }

        BigDecimal resizeFactor = new BigDecimal(rf);
        BigDecimal rounded = resizeFactor.setScale(2,BigDecimal.ROUND_HALF_UP);
        double result = rounded.doubleValue();

        return new ResizeFactor(result, result);
    }

    public String toString() {
        return resizeX+","+resizeY;
    }
}
```

```
package londonsw.model.simulation.components;

import java.io.Serializable;
import java.util.ArrayList;

/**
 * Each road is connected to at most 2 intersections (one at each end)
 * Each road is composed of a number of lanes (currently 2, one for each directi
on)
 * These are like the edges in our directed graph
 * Each has a start-location and an end-location
 */
public class Road implements Component, Serializable, IRoad {

    private static final long serialVersionUID = 6679898165504556586L;
    private Coordinate start;
    private Coordinate end;
    private ArrayList<Lane> lanes;
    private Intersection intersection;
    private static int counter = 0;

    public int getId() {
        return id;
    }

    public void setId(int id) {
        this.id = id;
    }

    private int id;

    /**
     * Creates an instance of a new Road. It has no lanes yet. (Note: a road wit
hout lanes
     * should not exist, so the user must specify lanes right away). A road can
have anywhere
     * between 1 and n lanes.
     * A road is defined by where it starts in the grid and where it ends in the
 grid.
     * The coordinates can be in any order, as long as they form a straight line
.
     *
     * @param start the location of one end of the road
     * @param end   the location of the other end of the road
     */
    public Road(Coordinate start, Coordinate end) {
        lanes = new ArrayList<Lane>();
        this.start = start;
        this.end = end;
        this.id = ++counter;
    }

    /**
     * Gets the number of lanes a road has
     *
     * @return number of lanes in the road
     */
    public ArrayList<Lane> getLanes() {
        return lanes;
    }

    /**
     * Adds a lane to the road
     *
     * @param l the Lane to add to the road
     */
    public void addLane(Lane l) {
        l.setRoad(this);
        l.setRoadIndex(lanes.size());
        lanes.add(l);
    }

    /**
     * Gets the lane at the index specified
     *
     * @param i index of lane
     * @return the instance of Lane at that index i
     */
    public Lane getLaneAtIndex(int i) {
        return lanes.get(i);
    }

    /**
     * Gets the beginning coordinate of the road
     *
     * @return location of beginning of road of type Coordinate
     */
    public Coordinate getStartLocation() {
        return start;
    }

    /**
     * Gets the end coordinate of the road
     *
     * @return location of end of road of type Coordinate
     */
    public Coordinate getEndLocation() {
        return end;
    }

    /**
     * Gets the number of lanes currently part of the road
     *
     * @return number of lanes in the road of type int
     */
    public int getNumberLanes() {
        return lanes.size();
    }

    public Intersection getIntersection() {
        //TODO
        return intersection;
    }

    public void setIntersection(Intersection intersection) {
        //TODO
        this.intersection = intersection;
    }
    public void setStart(Coordinate start) {
        this.start = start;
    }

    public void setEnd(Coordinate end) {
        this.end = end;
    }

    /**
     * Uses the coordinates to determine how long the road is
     * A road has a minimum length of 1
     *
     * @return length of the road
     */
    public int getLength() {
        int aX = start.getX();
        int aY = start.getY();
        int bX = end.getX();
        int bY = end.getY();
        int length;

        if (aX == bX) {
            length = Math.abs(aY − bY) + 1;
            return length;
        } else if (aY == bY) {
            length = Math.abs(aX − bX) + 1;
            return length;
        } else
            return −1;
    }

    /**
     * Determines if a road runs NORTH to SOUTH
     *
     * @return true if the road runs NORTH to SOUTH or SOUTH to NORTH, false if
the road runs EAST to WEST or WEST to EAST
     */
    public boolean runsVertically() {
        int aX = start.getX();
        int bX = end.getX();
        int aY = start.getY();
        int bY = end.getY();

        // if aX==bX, then road runs vertically
        if (aX == bX) {
            if(aY == bY) {
                // the road is length of 1, do something else
                if(lanes.size() == 0) {
                    return true;
                } else {
                    Lane lane = lanes.get(0);
                    if(lane.getMovingDirection() == MapDirection.NORTH || lane.g
etMovingDirection() == MapDirection.SOUTH) {
                        return true;
                    } else {
                        return false;
                    }
                }
            }
            return true;
        }

        // if aY==bY, then road runs horizontally
        return false;
    }

    public boolean runsVertically(MapDirection mapDirection) {

        if (mapDirection.equals(mapDirection.NORTH) || mapDirection.equals(mapDi
rection.SOUTH))
            return true;
        else
            return false;
    }
}
```

```
package londonsw.model.simulation.components;

import londonsw.controller.TrafficLightController;
import londonsw.model.simulation.Ticker;
import rx.Subscriber;

import java.io.Serializable;

/**
 * The implementation of the traffic lights in our system. This extends the RxJa
va class Subscriber to receive
 * messages from the Ticker.
 */
public class TrafficLight extends Subscriber<Long> implements Serializable {

    private static final long serialVersionUID = 1299747948664926447L;
    private LightColour state;
    private long duration;
    private long currentTime;
    private static int counter = 0;
    private int id;

    /**
     * Default constructor, initial light color is red
     */
    public TrafficLight() {
        this.currentTime = 1000;
        Ticker.subscribe(this);
        this.state = LightColour.RED;
        this.id = ++counter;
        this.duration = TrafficLightController.getInstance().getDurationLength()
;
    }

    /**
     * Creating a new traffic light with a new default color
     * @param colour the initial color of the traffic light
     */
    public TrafficLight(LightColour colour) {
        this.currentTime = 1000;
        Ticker.subscribe(this);
        this.state = colour;
        this.id = ++counter;
        this.duration = TrafficLightController.getInstance().getDurationLength()
;
    }

    /**
     * Subscribes this traffic light to the Ticker. Especially useful if using a
 loaded map!
     */
    public void subscribeToTicker() {
        Ticker.subscribe(this);
    }

    /**
     * Get the current color of the traffic light
     * @return LightColour (enum) of the current colour
     */
    public LightColour getState() {
        return state;
    }

    /**
     * Gets the ID of the traffic light, useful for logging
     * @return the id of this traffic light instance
     */
    public int getId() {
        return id;
    }

    /**
     * Sets the id of the traffic light
     * @param id the desired id of the traffic light
     */
    public void setId(int id) {
        this.id = id;
    }

    /**
     * Set the color of the traffic light from an external source
     * @param state LightColour (enum) of the color to be
     */
    public void setState(LightColour state) {
        this.state = state;
    }

    /**
     * Set the color of the traffic light based on the current state.
     * Current behaviour:
     * If currently red, go to green
     * If currently green, go to red
     */
    public void nextState() {
        switch (state) {
            case RED:
                state = LightColour.GREEN;
                break;
            case YELLOW:
                state = LightColour.RED;
                break;
            case GREEN:
                state = LightColour.RED; // changed to RED, no yellow behaviour
for now
                break;
            default:
                state = LightColour.RED;
                break;
        }

    }

    /**
     * Set how long the traffic light should be a specific color
     * @param duration time (in millis) of how long the traffic light should sta
y its color
     */
    public void setDuration(long duration) {
        this.duration = duration;

    }

    /**
     * Get the current duration of the traffic light (how long a color lasts)
     * @return the duration (in millis)
     */
    public long getDuration() {
        return duration;
    }


    /**
     * This is for what the traffic light would do if the ticker stops. Left uni
mplemented on purpose
     */
    @Override
    public void onCompleted() {    }

    /**
     * This is what the traffic light would do if there is an error thrown by th
e ticker’s observable. Left
     * unimplemented on purpose
     * @param throwable
     */
    @Override
    public void onError(Throwable throwable) {   }

    /**
     * This is like the onTick method. This is what happens when the ticker tick
s. The state changes after
     * a specified amount of ticks (the duration).
     * @param aLong the current time in the system
     */
    @Override
    public void onNext(Long aLong) {
        if(currentTime < (duration)) {
            currentTime += 1000;
        }
        else {
            currentTime = 1000;
            nextState();
            TrafficLightController.getInstance().colourChanged(state, this);
        }
    }
}
```

```java
package londonsw.model.simulation.components;

import java.util.Arrays;
import java.util.Collections;
import java.util.List;
import java.util.Random;

/**
 * This enum is to represent different types of behaviours vehicles can have. Fo
r instance, a Car might have average
 * behaviour, but an Ambulance has aggressive behaviour.
 */
public enum VehicleBehavior{
    AVERAGE, CAUTIOUS, AGGRESSIVE;

    private static final java.util.List<VehicleBehavior> VALUES= Collections.unm
odifiableList(Arrays.asList(values()));
    private static final int size = VALUES.size();
    private static  final Random RANDOM= new Random();
    public static VehicleBehavior randomLetter(){
        return VALUES.get(RANDOM.nextInt(size));
    }
}
```

```
package londonsw.model.simulation.components.vehicles;

import londonsw.model.simulation.components.Lane;


public class Ambulance extends Vehicle {


    /**
     * Create a vehicle and set its position by specify a cell in a lane
     *
     * @param currentCell the cell to set vehicle in, in the lane
     * @param currentLane the lane to set vehicle in
     */
    //TODO: Ambulance ignoring traffic light and blinking lights
    // TODO: figure out why ambulance gets stuck after moving forward
    public Ambulance(int currentCell, Lane currentLane) {
        super(currentCell, currentLane);
        this.vehicleLength=1;
        this.vehicleSpeed=1.0;
        this.vehiclePriority = 5;
        this.vehicleBehavior = vehicleBehavior.AGGRESSIVE;

    }
}
```

```
package londonsw.model.simulation.components.vehicles;
import londonsw.model.simulation.components.Lane;
import londonsw.model.simulation.components.VehicleBehavior;

import java.io.Serializable;

/**
 * An implementation of a vehicle
 * This moves in a lane
 * Only moves forwards when the slot in front of it is empty
 */


public class Car extends Vehicle implements Serializable, ICar {

    private static final long serialVersionUID = -3555254273903868035L;
    private static int idCounter = 0;
    private int id;

    public Car(int currentCell,Lane currentLane) {
        super(currentCell,currentLane);
        this.vehicleLength=1;
        this.vehicleSpeed=1.0;
        this.vehiclePriority = 1;
        this.vehicleBehavior = VehicleBehavior.AVERAGE; // default

        id = idCounter++;
    }

    public int getCarId() { return id; }

  }
```

```
package londonsw.model.simulation.components.vehicles;

/**
 * Created by felix on 26/02/2016.
 */
public interface ICar {

    int getCarId();

}
```

```java
package londonsw.model.simulation.components.vehicles;

import londonsw.model.simulation.components.Coordinate;
import londonsw.model.simulation.components.Lane;
import londonsw.model.simulation.components.TrafficLight;
import londonsw.model.simulation.components.VehicleBehavior;

import java.util.ArrayList;

/**
 * Created by felix on 04/03/2016.
 */
public interface IVehicle {

    Lane getPreviousLane();
    void setPreviousLane(Lane previousLane);
    void setCurrentCoordinate(Coordinate currentCoordinate);
    int getVehicleLength();
    double getVehicleSpeed();
    int getVehiclePriority();
    Lane getCurrentLane();
    int getCurrentCell();
    int getVehicleState();
    VehicleBehavior getVehicleBehavior();
    Coordinate getCurrentCoordinate();
    void setVehicleLength(int vehicleLength);
    void setVehicleSpeed(double vehicleSpeed);
    void setVehiclePriority(int vehiclePriority);
    void setCurrentLane(Lane currentLane) throws Exception;
    void setCurrentCell(int curCell,Lane currentLane) throws Exception;
    void setVehicleState(int vehicleState);
    void setVehicleBehavior(VehicleBehavior vehicleBehavior);
    Lane chooseLane () throws Exception;
    int moveVehicle(int step) throws Exception;//changed return type to int
    void readTrafficLight() throws Exception;
    ArrayList<Lane> getLaneOptions() throws Exception;
    int vehicleTurn (Lane l) throws Exception; //changed return type to int
    Coordinate getStoredCurrentCoordinate();
    void setPreviousCoordinate(Coordinate coord);

     int getVehiclePriorityToTurn();
     void setVehiclePriorityToTurn(int vehiclePriorityToTurn);
     TrafficLight getVehicleTrafficLight();
     void setVehicleTrafficLight(TrafficLight vehicleTrafficLight);
}
```

```
package londonsw.model.simulation.components.vehicles;
import londonsw.controller.TrafficLightController;
import londonsw.controller.VehicleController;
import londonsw.model.simulation.Ticker;
import londonsw.model.simulation.components.*;
import rx.Subscriber;

import java.io.Serializable;
import java.util.ArrayList;
import java.util.Random;


/**
 * This is the abstract class that all vehicles will implement
 * This allows for scalability because we can add more types of cars (eg. ambula
nce, bus)
 *
 * This uses RxJava’s Subscriber class to subscribe to the Ticker (that has as O
bservable). On each tick,
 * the onNext(..) method runs.
 */
public abstract class Vehicle extends Subscriber<Long> implements Serializable {

    private static final long serialVersionUID = −4552832373570448039L;
    protected int vehicleLength;
    protected double vehicleSpeed;
    protected int currentCell;
    protected int vehiclePriority;// 1 is the lowest
    protected int vehicleState;
    protected VehicleBehavior vehicleBehavior;
    protected  Lane currentLane;
    protected  ArrayList<Lane> laneOptions = new ArrayList<Lane>();
    protected  Random randomDirection;
    protected Lane l;
    protected Coordinate currentCoordinate;
    protected  Coordinate previousCoordinate;
    protected  Lane previousLane;
    protected int vehiclePriorityToTurn;
    protected TrafficLight vehicleTrafficLight;
    protected int timesTicked;
    private static int counter = 0;
    protected int id;
    protected int timeSpentStanding;


    /**
     * Create a vehicle and set its position by specify a cell in a lane
     *
     * @param currentCell the cell to set vehicle in, in the lane
     * @param currentLane the lane to set vehicle in
     */
    public Vehicle(int currentCell, Lane currentLane) {
        this.currentCell = currentCell;
        this.currentLane = currentLane;
        this.currentLane.setCell(this, currentCell);
        Ticker.subscribe(this);
        timesTicked = 0;
        id = ++counter;
        timeSpentStanding = 0;
    }

    /**
     * gets the traffic light that vehicle must read
     * @return traffic light in front of a vehicle in type of traffic light
     */
    public TrafficLight getVehicleTrafficLight() {
        return vehicleTrafficLight;
    }

    /**
     * sets the traffic light for vehicle
     * @param vehicleTrafficLight traffic light in front of vehicle
     */
    public void setVehicleTrafficLight(TrafficLight vehicleTrafficLight) {
        this.vehicleTrafficLight = vehicleTrafficLight;
    }


    /**
     * sets the vehicle priority to turn
     * @param vehiclePriorityToTurn the Priority Of vehicle To turn first int ty
pe of integer
     * in each intersection if there are more than vehicle, vehicles are given p
riorities to decide which turn first
     * so they do not crash
     */
    public void setVehiclePriorityToTurn(int vehiclePriorityToTurn) {
        this.vehiclePriorityToTurn = vehiclePriorityToTurn;
    }


    /**
     * gets vehicle priority to turn ,
     * @return the Priority Of vehicle To which turn first ib type of integer
     *depends on its priority its turns or stops
     */
    public int getVehiclePriorityToTurn() {
        return vehiclePriorityToTurn;
    }

    /**
     * gets a unique vehicle ID
     * @return  ID of vehicle in type of integer
     */
    public int getId() {
        return id;
    }

    /**
     * sets a unique ID for vehicle
     * @param id  unique ID for vehicle in type of integer
     */
    public void setId(int id) {
        this.id = id;
    }

    /**
     * Gets the length of a vehicle
     *
     * @return the length of a vehicle in type of integer
     * each type of vehicle has its own length
     */
    public int getVehicleLength() {
        return vehicleLength;
    }

    /**
     * Gets the speed of a vehicle
     *
     * @return the speed of a vehicle in type of double
     * each vehicle’s speed depends on its behavior
     */
    public double getVehicleSpeed() {
        return vehicleSpeed;
    }


    public int getVehiclePriority() {
        return vehiclePriority;
    }

    /**
     * Gets the lane which is vehicle in
     *
     * @return the lane which is vehicle in on the current time in type of lane
     */
    public Lane getCurrentLane() {
        return currentLane;
    }

    /**
     * Gets the current cell in lane which is vehicle in
     *
     * @return cell from lane which is vehicle in on the current time , in type
of integer
     */
    public int getCurrentCell() {
        return currentCell;
    }

    /**
     * Gets the state of vehicle which are 0 refers to still or 1 refers to movi
ng
     *
     * @return the state of vehicle in type if integer
     */
    public int getVehicleState() {
        return vehicleState;
    }

    /**
     * Gets the behavior of a vehicle from three behaviors AVERAGE, AGGRESSIVE,
and CAUTIOUS
     *
     * @return the behavior of a vehicle in type of enum VehicleBehavior
     */
    public VehicleBehavior getVehicleBehavior() {
        return this.vehicleBehavior;
    }

    /**
     * Gets the previous lane which vehicle was in
     * @return the previous lane in type of Lane
     */
    public Lane getPreviousLane() {
        return previousLane;
    }

    public void setPreviousCoordinate(Coordinate prev) {
        this.previousCoordinate = prev;
    }

    public void setPreviousLane(Lane previousLane) {
        this.previousLane = previousLane;
    }

    public Coordinate getPreviousCoordinate() {
        return previousCoordinate;
    }

    /**
     * Increments the time spent standing by this vehicle. This exists because t
he VehicleController needs
     * to call this for all stationary vehicles.
     */
    public void incrementTimeSpentStanding() {
        timeSpentStanding++;
    }

    /**
     * Gets the time spent standing (not moving) in the system
     * @return the total time spent standing by this vehicle in the system
     */
    public int getTimeSpentStanding() {
        return timeSpentStanding;
    }

    /**
     * Gets the times ticked by this vehicle in the system. This is used in the
calculation for the average vehicle time
     * standing in the system.
     * @return the number of ticks this vehicle heard
     */
    public int getTimesTicked() {
        return timesTicked;
    }


    /**
     * Gets the current coordinate of this vehicle in the Map
     * @return the current coordinate of this vehicle in the Map
     */
    public Coordinate getCurrentCoordinate() {
        int currentCell = this.getCurrentCell();
        Lane currentLane = this.getCurrentLane();
        Coordinate coordinate = new Coordinate(0, 0);
        MapDirection mapDirection = currentLane.getMovingDirection();


        switch (mapDirection) {
            case NORTH:
                coordinate.setX(currentLane.getEntry().getX());
                coordinate.setY(currentLane.getEntry().getY() − currentCell);
                break;

            case SOUTH:
                coordinate.setX(currentLane.getEntry().getX());
                coordinate.setY(currentLane.getEntry().getY() + currentCell);
                break;

            case EAST:
                coordinate.setX(currentLane.getEntry().getX() + currentCell);
                coordinate.setY(currentLane.getEntry().getY());
                break;

            case WEST:
                coordinate.setX(currentLane.getEntry().getX() − currentCell);
                coordinate.setY(currentLane.getEntry().getY());
                break;
        }

        this.currentCoordinate = coordinate;

        return coordinate;
    }

    public Coordinate getStoredCurrentCoordinate() {
        return currentCoordinate;
    }
    //Setter

    /**
     * @param vehicleLength the length of a vehicle in type of integer
     */
    public void setVehicleLength(int vehicleLength) {
        this.vehicleLength = vehicleLength;
    }

    /**
     * @param vehicleSpeed the speed of vehicle in type of double
     */
    public void setVehicleSpeed(double vehicleSpeed) {
        this.vehicleSpeed = vehicleSpeed;
    }

    public void setVehiclePriority(int vehiclePriority) {
        this.vehiclePriority = vehiclePriority;
    }


    /**
     * @param currentLane a lane to set car in, in type of lane
     * @throws Exception if lane is not exist
     *                    set a vehicle into a new lane
     */
    public void setCurrentLane(Lane currentLane) throws Exception {
        if (currentLane != null) {
            this.currentLane = currentLane;
        } else
            throw new Exception("Lane is not Exist !");
    }

    /**
     * @param curCell     new cell to assign vehicle to
     * @param currentLane lane that cell takes place in
     * @throws Exception if the cell is out of bounds or is not empty
     *                   <p>
     *                   set a vehicle into a new cell
     *                   check if a new cell is empty, and not out of bounds
     *                   not less than zero or equal or more than lane length
     */
    public void setCurrentCell(int curCell, Lane currentLane) throws Exception {
        if ((curCell >= 0) && (curCell < currentLane.getLength()) && (currentLan
e.isCellEmpty(curCell))) {
            this.currentCell = curCell;
        } else if (this.getVehiclePriority() != 5) {
            throw new Exception("new cell is not available !");
        }
    }

    /**
     * @param vehicleState in type of integer
     *                     set the state of vehicle
     *                     0 for still and 1 for movement
     */
    public void setVehicleState(int vehicleState) {
        this.vehicleState = vehicleState;
    }

    /**
     * @param vehicleBehavior in type of VehicleBehavior enum
     *                        sets the behavior of a vehicle
     *                        there are three behaviors AVERAGE, AGGRESSIVE, and
 CAUTIOUS
     */
    public void setVehicleBehavior(VehicleBehavior vehicleBehavior) {
        this.vehicleBehavior = vehicleBehavior;
    }

    public void setCurrentCoordinate(Coordinate currentCoordinate) {
        this.currentCoordinate = currentCoordinate;
    }

    /**
     * @param step number of steps to move, depends on the behavior
     * @return returns the number of steps the vehicle is able to achieve
     * @throws Exception vehicle can move one step or more, depends on its behav
ior
     *                   if it moves two steps, should check if this movement is
 available
     *                   if not it checks if one step is available
     *                   if not vehicle stops
     */
    public int moveVehicle(int step) throws Exception {

        int curCell = this.getCurrentCell();

        while (step > 0) {
            if (curCell + step >= this.currentLane.getLength() || !this.currentL
ane.isCellEmpty(curCell + step)) {
                step--;
            } else
                break;
        }

            currentLane.setCell(null, curCell);
            curCell += step;
            this.setCurrentCell(curCell, this.getCurrentLane());
            currentLane.setCell(this, curCell);

            return step;
        }



    /**
     * to make a vehicle reads a traffic light
     * use intersection to read the traffic light, each intersection has up to f
our traffic light
     * depends on the direction of a lane which vehicle is in, a vehicle can rea
ds the corresponding traffic light
     * if the traffic light is green the vehicle state set to moving
     * if the traffic light is red the vehicle state set to still
     * @throws Exception
     */
    public void readTrafficLight()throws Exception {
        if (this.getCurrentCell() == this.currentLane.getLength() - 1) {
            TrafficLight light;

            // traffic lights are disabled, allow cars to move through lights
            if(!TrafficLightController.getInstance().areLightsEnabled()) {
                this.setVehicleState(1);
                return;
            }

            if (this.getCurrentLane().getEndIntersection() != null) {
                switch (this.getCurrentLane().getMovingDirection()) {
                    case NORTH:
                        light = this.getCurrentLane().getEndIntersection().getSo
uthTrafficLight();
                        break;
                    case SOUTH:
                        light = this.getCurrentLane().getEndIntersection().getNo
rthTrafficLight();
                        break;
                    case EAST:
                        light = this.getCurrentLane().getEndIntersection().getWe
stTrafficLight();
                        break;
                    case WEST:
                        light = this.getCurrentLane().getEndIntersection().getEa
stTrafficLight();
```

```
                        break;
                    default: // ERROR case
                        light = null;
                        throw new Exception("Error Direction!");
                        // break;
                }

                if (this.getVehiclePriority() > 1 && light != null) {
                    if (light.getState() == LightColour.RED) {
                        this.vehicleState = 1;

                    }
                } else if (light != null) {
                    if (light.getState() == LightColour.RED)
                        this.vehicleState = 0;
                    else
                        this.vehicleState = 1;
                }
                else
                {
                    //move because there isn't any traffic light
                    this.setVehicleState(1);

                }
            } else {
                int curCell = this.getCurrentCell();
                currentLane.setCell(null, curCell);
                this.setVehicleState(3);
                this.unsubscribe();
                VehicleController.removeFromListAndMap(this);
            }


        } else
            throw new Exception("Reading traffic light when not at end of lane");
    }

    /**
     * in each intersection this method gives vehicles options of available lane
s that vehicles can move to
     * this method checks three conditions
     * 1. if the lane is exist
     * 2. if there is a space for a new vehicle
     * 3. if the direction of a lane is legal for the vehicle
     * if  a lane obtains these conditions, then it is added to laneOptions Arra
y List
     * @return  the options of lanes that vehicle can move to in type of Array L
ist of lanes
     * @throws Exception
     */
    public ArrayList<Lane> getLaneOptions() throws Exception {
        laneOptions.clear();

        if(this.currentLane.getEndIntersection()!=null) {
            if ((this.currentLane.getEndIntersection().getEastRoad() != null) &&
                    (this.currentLane.getMovingDirection() != MapDirection.WEST)
) {
                for (int i = 0; i < this.currentLane.getEndIntersection().getEas
tRoad().getNumberLanes(); i++) {
```

```
                    if ((this.currentLane.getEndIntersection().getEastRoad().get
LaneAtIndex(i).getMovingDirection() == MapDirection.EAST)
                            && (this.currentLane.getEndIntersection().getEastRoa
d().getLaneAtIndex(i).getState() == 1)) {
                        laneOptions.add(this.currentLane.getEndIntersection().ge
tEastRoad().getLaneAtIndex(i));
                    }
                }
            }

            if ((this.currentLane.getEndIntersection().getSouthRoad() != null) &
&
                    (this.currentLane.getMovingDirection() != MapDirection.NORTH
)) {
                for (int i = 0; i < this.currentLane.getEndIntersection().getSou
thRoad().getNumberLanes(); i++) {
                    if ((this.currentLane.getEndIntersection().getSouthRoad().ge
tLaneAtIndex(i).getMovingDirection() == MapDirection.SOUTH)
                            && (this.currentLane.getEndIntersection().getSouthRo
ad().getLaneAtIndex(i).getState() == 1)) {
                        laneOptions.add(this.currentLane.getEndIntersection().ge
tSouthRoad().getLaneAtIndex(i));
                    }
                }
            }

            if ((this.currentLane.getEndIntersection().getNorthRoad() != null) &
&
                    (this.currentLane.getMovingDirection() != MapDirection.SOUTH
)) {
                for (int i = 0; i < this.currentLane.getEndIntersection().getNor
thRoad().getNumberLanes(); i++) {
                    if ((this.currentLane.getEndIntersection().getNorthRoad().ge
tLaneAtIndex(i).getMovingDirection() == MapDirection.NORTH)
                            && (this.currentLane.getEndIntersection().getNorthRo
ad().getLaneAtIndex(i).getState() == 1)) {
                        laneOptions.add(this.currentLane.getEndIntersection().ge
tNorthRoad().getLaneAtIndex(i));
                    }
                }
            }

            if ((this.currentLane.getEndIntersection().getWestRoad() != null) &&
                    (this.currentLane.getMovingDirection() != MapDirection.EAST)
) {
                for (int i = 0; i < this.currentLane.getEndIntersection().getWes
tRoad().getNumberLanes(); i++) {
                    if ((this.currentLane.getEndIntersection().getWestRoad().get
LaneAtIndex(i).getMovingDirection() == MapDirection.WEST)
                            && (this.currentLane.getEndIntersection().getWestRoa
d().getLaneAtIndex(i).getState() == 1)) {
                        laneOptions.add(this.currentLane.getEndIntersection().ge
tWestRoad().getLaneAtIndex(i));
                    }
                }
            }

            return laneOptions;
        }
        return null;
    }





    /**
     * Chooses lane randomly from lanes options
     * @return a random lane in type of Lane
     * @throws Exception
     */
    public Lane chooseLane() throws Exception {
        int num = 0;


        if(this.getLaneOptions()!=null) {
            num = this.getLaneOptions().size();
        }

        if (num > 0) {
            randomDirection = new Random();
            int size = randomDirection.nextInt(this.getLaneOptions().size());
            l= this.getLaneOptions().get(size);
            return l;
        }

        return null;
    }


    /**
     * there are four condition for vehicle to turn:
     * 1. if the lane is exist and
     * 2. the vehicle is at the last cell of the lane
     * 3. the first cell is empty
     * 4. the vehicle priority to turn is 1
     * if these conditions are obtained vehicle turn
     * otherwise vehicle stops
     * @param l a random lane to move to in type of Lane
     * @return integer representation of booleans
     * @throws Exception
     */
    public int vehicleTurn(Lane l) throws Exception {
        Lane oldLane = this.currentLane;


            //validate if its end of lane
            if (((l != null) && (this.getCurrentCell() == this.currentLane.getLe
ngth() -1) && (l.isCellEmpty(0)) && this.getVehiclePriorityToTurn()==1) ||
                    (l != null && this.getCurrentCell() == this.currentLane.getL
ength()-1 && l.isCellEmpty(0) && !TrafficLightController.getInstance().areLights
Enabled()))
                {
                    oldLane.setCell(null, oldLane.getLength() - 1);
                    this.setCurrentLane(l);
                    this.setCurrentCell(0, l);
                    this.getCurrentLane().setCell(this,0);
                    return 1;
                }

            else {
                this.setVehicleState(0);
                return 0;}

    }




    /**
     * This is the method that gets called when the ticker terminates (i.e. the
stop() method was called
     * on the ticker). Left not implemented on purpose
     */
    @Override
    public void onCompleted() {    }

    /**
     * If there’s some error with the ticker and this subscriber, this method wo
uld call.
     * Left not implemented on purpose
     * @param throwable
     */
    @Override
    public void onError(Throwable throwable) {    }

    /**
     * This is like the onTick method. This is what cars would do when the ticke
r ticks.
     * @param aLong this gives the current time in the system to the car (althou
gh it is probably not required)
     */
    @Override
    public void onNext(Long aLong) {
//        System.out.print("Tick! " + aLong + "     ");
//        System.out.println("Car: "+ this.getId()+"  Location: " + this.getCurr
entCoordinate().getX() + "," + this.getCurrentCoordinate().getY());
        timesTicked++;
        try {
            if (vehicleBehavior == VehicleBehavior.AVERAGE) {
                VehicleController.moveOnTick(this,1);
            } else if (vehicleBehavior == VehicleBehavior.AGGRESSIVE) {
                VehicleController.moveOnTick(this,2);
            } else if (vehicleBehavior == VehicleBehavior.CAUTIOUS) {
                VehicleController.moveOnTick(this,1);
            } else
            {
                VehicleController.moveOnTick(this,1); // default behaviour
            }
        } catch(Exception e) {
            e.printStackTrace();
        }
    }
}
```

```java
package londonsw.view.mapcreation;

/**
 * Created by violet on 17/03/2016.
 */
public enum ComponentType {
    INTERSECTION,
    ROADNS,
    ROADEW,
    MAP_SQUARE,
    GRASS,
    NOTHING
}
```

```
package londonsw.view.mapcreation;

import javafx.application.Platform;
import javafx.beans.value.ObservableValue;
import javafx.collections.ObservableList;
import javafx.fxml.FXMLLoader;
import javafx.geometry.Insets;
import javafx.scene.Node;
import javafx.scene.Parent;
import javafx.scene.Scene;
import javafx.scene.control.*;
import javafx.scene.effect.DropShadow;
import javafx.scene.image.Image;
import javafx.scene.image.ImageView;
import javafx.scene.input.MouseEvent;
import javafx.scene.layout.*;
import javafx.scene.paint.Color;
import javafx.scene.text.Font;
import javafx.scene.text.FontWeight;
import javafx.stage.Stage;
import londonsw.controller.MapMakerController;
import londonsw.controller.StartUpController;
import londonsw.model.simulation.Map;
import londonsw.model.simulation.Ticker;
import londonsw.model.simulation.components.*;
import londonsw.view.simulation.MapGridGUIDecorator;

import java.util.ArrayList;
import java.util.Optional;


@SuppressWarnings("Duplicates")
public class MapMakerScreen {

    private int width;
    private int height;

    private ImageView intersectionImgView;
    private ImageView roadNSImgView;
    private ImageView roadEWImgView;
    private ImageView grassImgView;

    /**
     * Creates a new MapMaker screen
     * @param width the width the user chose for their map
     * @param height the height the user chose for their map
     */
    public MapMakerScreen(int width, int height) {
        this.width = width;
        this.height = height;
    }

    /**
     * Draws the MapMaker screen and displays it to the user
     * @param primaryStage the stage to show it in
     * @throws Exception
     */
    public void drawScreen(Stage primaryStage) throws Exception {
        // Create the base BorderPane for the whole window
        BorderPane borderPane = new BorderPane();
        borderPane.setStyle("−fx−background−color: papayawhip");

        // Add some instructions to the user
        String text = "Instructions:\n" +
                "1. Click on the map component that you would like to place in the map\n" +
                "2. Click on the place in the map where you want to place the component\n" +
                "3. Repeat until you built the map you want!\n" +
                "4. Hit the 'Save' button when you are done";
        Label instructions = new Label(text);
        instructions.setFont(Font.font("Arial", FontWeight.BOLD,12));
        instructions.setPadding(new Insets(5, 5, 5, 5));
        borderPane.setTop(instructions);

        // Create the blank Map
        Pane mapPane = new Pane();
        Map map = new Map(width, height);
        MapGridGUIDecorator mapGridGUIDecorator = new MapGridGUIDecorator(map.ge
tGrid());
        ResizeFactor rf = ResizeFactor.getSuggestedResizeFactor(width, height);
        mapGridGUIDecorator.setResizeFactor(rf);
        GridPane mapGridPane = mapGridGUIDecorator.drawComponents();
        mapGridPane.setPadding(new Insets(0,0,5,5));
        mapPane.getChildren().add(mapGridPane);
        borderPane.setCenter(mapPane);
        MapMakerController.setCurrentFocused(ComponentType.NOTHING);

        VBox sideComponents = new VBox();

        /* Add "Components" label */
        Label componentsLabel = new Label("Components");
        componentsLabel.setFont(Font.font("Arial",FontWeight.EXTRA_BOLD,14));
        componentsLabel.setPadding(new Insets(15,5,0,20));
        sideComponents.getChildren().add(componentsLabel);

        /* Add Intersection square image */
        VBox intersectionPane = new VBox();
        Label intersectionLabel = new Label("Intersection");
        intersectionLabel.setPadding(new Insets(5,5,0,30));
        intersectionLabel.setFont(Font.font("Arial",FontWeight.SEMI_BOLD,12));
        Image intersectionImg = new Image("IntersectionX.png",60,60,true,false);
        intersectionImgView = new ImageView(intersectionImg);
        StackPane intersectionStackPane = new StackPane(intersectionImgView);
        intersectionStackPane.setPadding(new Insets(0,10,10,10));
        intersectionPane.getChildren().add(intersectionLabel);
        intersectionPane.getChildren().add(intersectionStackPane);
        sideComponents.getChildren().add(intersectionPane);

        /* Add RoadNS square image */
        VBox roadNSPane = new VBox();
        Label roadNSLabel = new Label("Road (North−South)");
        roadNSLabel.setPadding(new Insets(5,5,0,15));
        roadNSLabel.setFont(Font.font("Arial",FontWeight.SEMI_BOLD,12));
        Image roadNSImg = new Image("RoadBackgroundNS.png",60,60,true,false);
        roadNSImgView = new ImageView(roadNSImg);
        StackPane roadNSStackPane = new StackPane(roadNSImgView);
        roadNSStackPane.setPadding(new Insets(0,10,10,10));
        roadNSPane.getChildren().add(roadNSLabel);
        roadNSPane.getChildren().add(roadNSStackPane);
        sideComponents.getChildren().add(roadNSPane);

        /* Add RoadEW square image */
        VBox roadEWPane = new VBox();
        Label roadEWLabel = new Label("Road (East−West)");
        roadEWLabel.setPadding(new Insets(5,5,0,15));
        roadEWLabel.setFont(Font.font("Arial",FontWeight.SEMI_BOLD,12));
        Image roadEWImg = new Image("RoadBackgroundEW.png",60,60,true,false);
        roadEWImgView = new ImageView(roadEWImg);
        StackPane roadEWStackPane = new StackPane(roadEWImgView);
        roadEWStackPane.setPadding(new Insets(0,10,10,10));
        roadEWPane.getChildren().add(roadEWLabel);
        roadEWPane.getChildren().add(roadEWStackPane);
        sideComponents.getChildren().add(roadEWPane);

        /* Add Grass square image to empty out cells */
        VBox grassPane = new VBox();
        Label grassLabel = new Label("Grass (clear square)");
        grassLabel.setPadding(new Insets(5,5,0,15));
        grassLabel.setFont(Font.font("Arial",FontWeight.SEMI_BOLD,12));
        Image grassImg = new Image("Grass.png",60,60,true,false);
        grassImgView = new ImageView(grassImg);
        StackPane grassStackPane = new StackPane(grassImgView);
        grassStackPane.setPadding(new Insets(0,10,10,10));
        grassPane.getChildren().add(grassLabel);
        grassPane.getChildren().add(grassStackPane);
        sideComponents.getChildren().add(grassPane);

        /* Add Save, Reset buttons */
        VBox buttonsPane = new VBox();
        buttonsPane.setPadding(new Insets(0,0,0,10));
        Label toolsLabel = new Label("Tools");
        toolsLabel.setFont(Font.font("Arial",FontWeight.EXTRA_BOLD,14));
        toolsLabel.setPadding(new Insets(15,5,5,35));
        buttonsPane.getChildren().add(toolsLabel);
        Insets padding = new Insets(0,0,5,0);
        Button saveButton = new Button("Save Map");
        StackPane saveButtonPane = new StackPane(saveButton);
        saveButtonPane.setPadding(padding);
        saveButton.setStyle("−fx−base:Gold");
        saveButton.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 13));
        buttonsPane.getChildren().add(saveButtonPane);
        Button resetButton = new Button("Reset Map");
        resetButton.setStyle("−fx−base:Gold");
        resetButton.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 13));
        StackPane resetButtonPane = new StackPane(resetButton);
        resetButtonPane.setPadding(padding);
        buttonsPane.getChildren().add(resetButtonPane);
        Button backButton = new Button("Go Back");
        backButton.setStyle("−fx−base:Gold");
        backButton.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 13));
        StackPane backButtonPane = new StackPane(backButton);
        backButtonPane.setPadding(padding);
        buttonsPane.getChildren().add(backButtonPane);

        sideComponents.getChildren().add(buttonsPane);

        Ticker.start();
        /* Add click processing for Map grid squares */
        for(int i = 0; i < height; i++) {
            for(int j = 0; j < width; j++) {
                Node current = getNodeFromIndex(i, j, mapGridPane);
                final int x = j;
                final int y = i;
                current.setOnMouseClicked((MouseEvent click) -> {
                    MapMakerController.setPreviousFocused(MapMakerController.get
CurrentFocused());
                    MapMakerController.setCurrentFocused(ComponentType.MAP_SQUAR
E);
                    current.requestFocus();
                });
                current.focusedProperty().addListener((ObservableValue<? extends
 Boolean> observable, Boolean oldValue, Boolean newValue) -> {
                    ComponentType previous = MapMakerController.getPreviousFocus
ed();
                    if(previous == ComponentType.INTERSECTION) {
                        addIntersection(x,y,map,mapGridGUIDecorator,mapGridPane,
intersectionImgView);
                    }
                    else if(previous == ComponentType.ROADNS) {
                        addRoadNS(x,y,map,mapGridGUIDecorator,mapGridPane,roadNS
ImgView);
                    }
                    else if(previous == ComponentType.ROADEW) {
                        addRoadEW(x,y,map,mapGridGUIDecorator,mapGridPane,roadEW
ImgView);
                    }
                    else if(previous == ComponentType.GRASS) {
                        addGrass(x,y,map,mapGridGUIDecorator,mapGridPane,grassIm
gView);
                    }
                });
            }
        }

        /* Add intersection icon click processing */
        DropShadow ds = new DropShadow(15, Color.BLUE);
        intersectionImgView.setOnMouseClicked(click -> {
            MapMakerController.setPreviousFocused(MapMakerController.getCurrentF
ocused());
            MapMakerController.setCurrentFocused(ComponentType.INTERSECTION);
            intersectionImgView.requestFocus();
        });
        intersectionImgView.focusedProperty().addListener((ObservableValue<? ext
ends Boolean> observable, Boolean oldValue, Boolean newValue) -> {
            if(newValue)
                intersectionImgView.setEffect(ds);
            else
                intersectionImgView.setEffect(null);
        });

        /* Add roadNS icon click processing */
        roadNSImgView.setOnMouseClicked(click -> {
            MapMakerController.setPreviousFocused(MapMakerController.getCurrentF
ocused());
            MapMakerController.setCurrentFocused(ComponentType.ROADNS);
            roadNSImgView.requestFocus();
        });
        roadNSImgView.focusedProperty().addListener((ObservableValue<? extends B
oolean> observable, Boolean oldValue, Boolean newValue) -> {
            if(newValue)
                roadNSImgView.setEffect(ds);
            else
                roadNSImgView.setEffect(null);
        });

        /* Add roadEW icon click processing */
        roadEWImgView.setOnMouseClicked(click -> {
            MapMakerController.setPreviousFocused(MapMakerController.getCurrentF
ocused());
            MapMakerController.setCurrentFocused(ComponentType.ROADEW);
            roadEWImgView.requestFocus();
        });
        roadEWImgView.focusedProperty().addListener((ObservableValue<? extends B
oolean> observable, Boolean oldValue, Boolean newValue) -> {
            if(newValue)
                roadEWImgView.setEffect(ds);
            else
                roadEWImgView.setEffect(null);
        });

        /* Add grass icon click processing */
        grassImgView.setOnMouseClicked(click -> {
            MapMakerController.setPreviousFocused(MapMakerController.getCurrentF
ocused());
            MapMakerController.setCurrentFocused(ComponentType.GRASS);
            grassImgView.requestFocus();
        });
        grassImgView.focusedProperty().addListener((ObservableValue<? extends Bo
olean> observable, Boolean oldValue, Boolean newValue) -> {
            if(newValue)
                grassImgView.setEffect(ds);
            else
                grassImgView.setEffect(null);
        });

        /* Add save button functionality */
        saveButton.setOnMouseClicked(click -> {
            TextInputDialog nameDialog = new TextInputDialog();
            nameDialog.setTitle("Save Map");
            nameDialog.setHeaderText("Please provide a name for your map (no spaces or special char
acters).\nSaved maps go into the /maps directory of your working directory.");
            nameDialog.setContentText("File name");
            Button btOk = (Button) nameDialog.getDialogPane().lookupButton(Butto
nType.OK);
            TextField textfield = nameDialog.getEditor();
            Platform.runLater(() -> textfield.requestFocus());
            btOk.setDisable(true);
            textfield.textProperty().addListener(((observable, oldValue, newValu
e) -> {
                btOk.setDisable(newValue.trim().isEmpty());
            }));

            Optional<String> result = nameDialog.showAndWait();
            result.ifPresent(name -> {
                name = name.concat(".map");
                try {
                    Map finalMap = buildAndSaveMap(map);
                    finalMap.saveMap(name);
                    goBack(primaryStage);
                } catch (Exception e) {
                    e.printStackTrace();
                }
            });
        });

        resetButton.setOnMouseClicked(click -> {
            for(int y = 0; y < height; y++) {
                for(int x = 0; x < width; x++) {
                    Component component = map.getAtLocation(new Coordinate(x, y)
);
                    if(component instanceof Road || component instanceof Interse
ction) {
                        addGrass(x,y,map,mapGridGUIDecorator,mapGridPane,grassIm
gView);
                    }
                }
            }
        });

        backButton.setOnMouseClicked(click -> {
            try {
                goBack(primaryStage);
            } catch (Exception e) {
                e.printStackTrace();
            }
        });

        borderPane.setRight(sideComponents);
        Scene scene = new Scene(borderPane);
        primaryStage.setScene(scene);
        primaryStage.centerOnScreen();
        primaryStage.setResizable(false);
    }

    /**
     * Build the map that the user drew into a complete and connected map
     * @param map the map that the user built
     * @return a fixed map that has all roads and intersections connected
     * @throws Exception
     */
    private Map buildAndSaveMap(Map map) throws Exception {
        System.out.println("Building and saving map...");
        int width = map.getWidth();
        int height = map.getHeight();
        Map fixed = new Map(width,height);

        for(int y = 0; y < height; y++) {
            for(int x = 0; x < width; x++) {
                Component current = map.getGrid().get(x, y);
                if(current instanceof Intersection) {
                    Coordinate location = new Coordinate(x, y);
                    Intersection i = new Intersection(location);
                    fixed.addIntersection(i);
                    deleteFromOldMap(map, location, location);
                }
                else if(current instanceof Road) {
                    Road road = (Road) current;
                    Coordinate lastKnownCoord = road.getEndLocation();

                    if(road.runsVertically()) {
                        if(lastKnownCoord.getY() != height-1) {
                            Component next = map.getGrid().get(x,y++);
                            while(next != null && next instanceof Road) {
                                lastKnownCoord = ((Road) next).getEndLocation();
                                if(y == height) break;
                                next = map.getGrid().get(x, y++);
                            }
                            y = road.getStartLocation().getY(); // go back to th
e row we started at
                        }
                        Coordinate start = road.getStartLocation();
                        Coordinate end = lastKnownCoord;
                        Road newRoad = new Road(start, end);
                        newRoad.addLane(new Lane(end, start, MapDirection.NORTH)
);
                        newRoad.addLane(new Lane(start, end, MapDirection.SOUTH)
);
                        fixed.addRoad(newRoad);
                        deleteFromOldMap(map, start, end);
                    }
                    else {
                        if(lastKnownCoord.getX() != width-1) {
                            Component next = map.getGrid().get(x++, y);
                            while (next != null && next instanceof Road) {
                                lastKnownCoord = ((Road) next).getEndLocation();
                                if(x == width) break;
                                next = map.getGrid().get(x++, y);
                            }
                            x = x - 2; // we overshot by 1, so go back, and loop
 will increment, so go back another
                        }
                        Coordinate start = road.getStartLocation();
                        Coordinate end = lastKnownCoord;
                        Road newRoad = new Road(start, end);
                        newRoad.addLane(new Lane(start, end, MapDirection.EAST))
;
                        newRoad.addLane(new Lane(end, start, MapDirection.WEST))
;
                        fixed.addRoad(newRoad);
                        deleteFromOldMap(map, start, end);
                    }
                }
            }
        }

        assignIntersectionsToRoads(fixed);
        return fixed;
    }

    /**
     * Gets the Node at a given location in the GridPane
     * @param row the row (y-coordinate) where to get the Node
     * @param column the column (x-coordinate) where to get the Node
     * @param gridPane the GridPane to get a Node from
     * @return the Node at that given location from the GridPane
     */
    private Node getNodeFromIndex(int row, int column, GridPane gridPane) {
        Node result = null;
        ObservableList<Node> childrens = gridPane.getChildren();
        for(Node node : childrens) {
            if(gridPane.getRowIndex(node) == row && gridPane.getColumnIndex(node
) == column) {
                result = node;
                break;
            }
        }
        return result;
    }

    /**
     * Adds an intersection to the map where the user clicks
     *
     * @param x the x coordinate where to add the intersection
     * @param y the y coordinate where to add the intersection
     * @param map the map to add the intersection to
     * @param mapGridGUIDecorator the GUI decorator associated with this map
     * @param mapGridPane the gridPane that would need to be updated with the ne
w view
     * @param imgView the associated image to place in the x,y cell
     */
    private void addIntersection(int x, int y, Map map, MapGridGUIDecorator mapG
ridGUIDecorator, GridPane mapGridPane, ImageView imgView) {
        Coordinate coord = new Coordinate(x,y);
        Intersection intersection = new Intersection(coord);
        map.addIntersection(intersection);
        StackPane sp = mapGridGUIDecorator.redrawCell(x,y,mapGridPane);

        sp.setOnMouseClicked(click -> {
            ComponentType currentFocused = MapMakerController.getCurrentFocused(
);
            if(currentFocused == ComponentType.ROADNS) {
                addRoadNS(x,y,map,mapGridGUIDecorator,mapGridPane,roadNSImgView)
;
            } else if(currentFocused == ComponentType.ROADEW) {
                addRoadEW(x,y,map,mapGridGUIDecorator,mapGridPane,roadEWImgView)
;
            } else if(currentFocused == ComponentType.GRASS) {
                addGrass(x,y,map,mapGridGUIDecorator,mapGridPane,grassImgView);
            }
        });

        // put focus back on Intersection
        MapMakerController.setPreviousFocused(MapMakerController.getCurrentFocus
ed());
        MapMakerController.setCurrentFocused(ComponentType.INTERSECTION);
        imgView.requestFocus();
    }

    /**
     * Adds a section of road with 2 lanes that travels in the directions north
and south
     *
     * @param x the x coordinate where to add the road
     * @param y the y coordinate where to add the road
     * @param map the map to add the road to
     * @param mapGridGUIDecorator the GUI decorator associated with this map
     * @param mapGridPane the gridPane that would need to be updated with the ne
w view
     * @param imgView the associated image to place in the x,y cell
     */
    private void addRoadNS(int x, int y, Map map, MapGridGUIDecorator mapGridGUI
Decorator, GridPane mapGridPane, ImageView imgView) {
        Coordinate coord = new Coordinate(x,y);
        Road road = new Road(coord,coord);
        try {
            road.addLane(new Lane(coord,coord,MapDirection.NORTH));
            road.addLane(new Lane(coord,coord,MapDirection.SOUTH));
            map.addRoad(road);
            StackPane sp = mapGridGUIDecorator.redrawCell(x,y,mapGridPane);

            sp.setOnMouseClicked(click -> {
                ComponentType currentFocused = MapMakerController.getCurrentFocu
sed();
                if(currentFocused == ComponentType.INTERSECTION) {
                    addIntersection(x,y,map,mapGridGUIDecorator,mapGridPane,inte
rsectionImgView);
                } else if(currentFocused == ComponentType.GRASS) {
                    addGrass(x,y,map,mapGridGUIDecorator,mapGridPane,grassImgVie
w);
                } else if(currentFocused == ComponentType.ROADEW) {
                    addRoadEW(x,y,map,mapGridGUIDecorator,mapGridPane,roadEWImgV
iew);
                }
            });

            // put focus back on RoadNS
            MapMakerController.setPreviousFocused(MapMakerController.getCurrentF
ocused());
            MapMakerController.setCurrentFocused(ComponentType.ROADNS);
            imgView.requestFocus();
        } catch (Exception e) {
            e.printStackTrace();
        }
    }

    /**
     * Adds a section of road with 2 lanes that travels in the directions east a
nd west
     *
     * @param x the x coordinate where to add the road
     * @param y the y coordinate where to add the road
     * @param map the map to add the road to
     * @param mapGridGUIDecorator the GUI decorator associated with this map
     * @param mapGridPane the gridPane that would need to be updated with the ne
w view
     * @param imgView the associated image to place in the x,y cell
     */
    private void addRoadEW(int x, int y, Map map, MapGridGUIDecorator mapGridGUI
Decorator, GridPane mapGridPane, ImageView imgView) {
        Coordinate coord = new Coordinate(x,y);
        Road road = new Road(coord,coord);
        try {
            road.addLane(new Lane(coord,coord,MapDirection.EAST));
            road.addLane(new Lane(coord,coord,MapDirection.WEST));
            map.addRoad(road);
            StackPane sp = mapGridGUIDecorator.redrawCell(x,y,mapGridPane);

            sp.setOnMouseClicked(click -> {
                ComponentType currentFocused = MapMakerController.getCurrentFocu
sed();
                if(currentFocused == ComponentType.INTERSECTION) {
                    addIntersection(x,y,map,mapGridGUIDecorator,mapGridPane,inte
rsectionImgView);
                } else if(currentFocused == ComponentType.ROADNS) {
                    addRoadNS(x,y,map,mapGridGUIDecorator,mapGridPane,roadNSImgV
iew);
                } else if(currentFocused == ComponentType.GRASS) {
                    addGrass(x,y,map,mapGridGUIDecorator,mapGridPane,grassImgVie
w);
                }
            });

            // put focus back on RoadEW
            MapMakerController.setPreviousFocused(MapMakerController.getCurrentF
ocused());
            MapMakerController.setCurrentFocused(ComponentType.ROADEW);
            imgView.requestFocus();
        } catch (Exception e) {
            e.printStackTrace();
        }
    }

    /**
     * Adds a "grass" component to the map, aka a null component
     * Useful if the user wants to delete a map component they placed in the map
     *
     * @param x the x coordinate where to add the grass
     * @param y the y coordinate where to add the grass
     * @param map the map to add the grass to
     * @param mapGridGUIDecorator the GUI decorator associated with this map
     * @param mapGridPane the gridPane that would need to be updated with the ne
w view
     * @param imgView the associated image to place in the x,y cell
     */
    private void addGrass(int x, int y, Map map, MapGridGUIDecorator mapGridGUID
ecorator, GridPane mapGridPane, ImageView imgView) {
        Coordinate coord = new Coordinate(x,y);
        map.clearCell(coord);

        StackPane sp = mapGridGUIDecorator.redrawCell(x,y,mapGridPane);

        sp.setOnMouseClicked(click -> {
            ComponentType currentFocused = MapMakerController.getCurrentFocused(
);
            if(currentFocused == ComponentType.INTERSECTION) {
                addIntersection(x,y,map,mapGridGUIDecorator,mapGridPane,intersec
tionImgView);
            } else if(currentFocused == ComponentType.ROADNS) {
                addRoadNS(x,y,map,mapGridGUIDecorator,mapGridPane,roadNSImgView)
;
```

```
            } else if(currentFocused == ComponentType.ROADEW) {
                addRoadEW(x,y,map,mapGridGUIDecorator,mapGridPane,roadEWImgView)
;
            }
        });

        // put focus back on Grass
        MapMakerController.setPreviousFocused(MapMakerController.getCurrentFocus
ed());
        MapMakerController.setCurrentFocused(ComponentType.GRASS);
        imgView.requestFocus();

    }

    /**
     * When saving a map, we are looping through the map that was built and addi
ng the fixed roads to a new map.
     * To prevent adding the same bits of roads again, delete all the bits from
the already added road
     *
     * @param oldMap the map from which to delete some number of components
     * @param start the start coordinate from where to begin deleting components
     * @param end the end coordinate to which we must delete all components
     */
    private void deleteFromOldMap(Map oldMap, Coordinate start, Coordinate end)
{
        int startX = start.getX();
        int startY = start.getY();
        int endX = end.getX();
        int endY = end.getY();

        if(startY == endY) { // horizontal
            for(int i = startX; i <= endX; i++) {
                oldMap.clearCell(new Coordinate(i, startY));
            }
        } else { // vertical
            for(int i = startY; i <= endY; i++) {
                oldMap.clearCell(new Coordinate(startX, i));
            }
        }
    }

    /**
     * Takes a map with disconnected Roads and Intersections and connects them.
This is like connecting nodes (intersections) to
     * edges (roads) in a directed graph.
     * @param fixed the map where components need to be connected
     */
    private void assignIntersectionsToRoads(Map fixed) throws Exception {
        ArrayList<Intersection> intersections = fixed.getIntersections();
        for(int i = 0; i < intersections.size(); i++) {
            Intersection current = intersections.get(i);
            Coordinate coord = current.getLocation();
            int x = coord.getX();
            int y = coord.getY();
            Coordinate north = (y−1 >= 0) ? new Coordinate(x, y−1) : null;
            Coordinate south = (y+1 < height) ? new Coordinate(x, y + 1) : null;
            Coordinate east = (x + 1 < width) ? new Coordinate(x + 1, y) : null;
            Coordinate west = (x − 1 >= 0) ? new Coordinate(x − 1, y) : null;
            if(north != null) {
                Component component = fixed.getAtLocation(north);
                if(component instanceof Road) {
                    current.setNorthRoad((Road) component);
                }
            }

            if(south != null) {
                Component component = fixed.getAtLocation(south);
                if(component instanceof Road) {
                    current.setSouthRoad((Road) component);
                }
            }

            if(east != null) {
                Component component = fixed.getAtLocation(east);
                if(component instanceof Road) {
                    current.setEastRoad((Road) component);
                }
            }

            if(west != null) {
                Component component = fixed.getAtLocation(west);
                if(component instanceof Road) {
                    current.setWestRoad((Road) component);
                }
            }

            current.setDefaultTrafficLightsForRoads();
        }
    }

    /**
     * Goes back to the previous screen (Choose mode screen)
     * @param stage the stage which will display the screen
     * @throws Exception
     */
    private void goBack(Stage stage) throws Exception {
        StartUpController.getInstance().goToChooseModeScreen(stage);
        stage.centerOnScreen();
        stage.setResizable(false);
    }

}
```

```
package londonsw.view.simulation;

import javafx.scene.Group;
import javafx.scene.Scene;
import javafx.scene.image.Image;
import javafx.scene.image.ImageView;
import javafx.scene.layout.Pane;
import javafx.scene.layout.StackPane;
import javafx.scene.paint.Color;
import javafx.stage.Stage;
import londonsw.controller.IntersectionController;
import londonsw.model.simulation.components.Intersection;
import londonsw.model.simulation.components.ResizeFactor;

import java.io.Serializable;

/**
 * Associates an Intersection GUI with an instance of an Intersection. Each has
up to 4
 * TrafficLightDecorators that live inside this GUI. The Intersection does not h
ave any
 * explicit circles itself, it relies on the circles of each TrafficLightDecorat
or that
 * is associated with each TrafficLight in the Intersection instance.
 *
 * Exactly one IntersectionDecorator is created for exactly one Intersection.
 */
public class IntersectionDecorator implements Serializable {

    private static final long serialVersionUID = -1977850713285364445L;
    private Intersection intersection;
    private int width = 100;
    private int height = 100;

    private TrafficLightDecorator northLight;
    private TrafficLightDecorator eastLight;
    private TrafficLightDecorator southLight;
    private TrafficLightDecorator westLight;

    private ResizeFactor resizeFactor;

    private Group root;
    private Scene scene;

    /**
     * Creates a GUI for that specific intersection. It creates TrafficLightDeco
rators for all
     * TrafficLights that are in this intersection. It draws and displays them i
n a Scene specified
     * by the global variables of width and height.
     * @param intersection an instance of an Intersection to associate this deco
rator
     */
    public IntersectionDecorator(Intersection intersection) {
        this.intersection = intersection;
        IntersectionController.addIntersectionAndDecoratorPair(intersection,this
);
    }
    /**
     * Sets the resize factor for this intersection GUI decorator
     * @param rf the resize factor to set for this decorator
     */
    public void setResizeFactor(ResizeFactor rf) {
        resizeFactor = rf;
    }

    /**
     * Sets the north traffic light decorator for this intersection to represent
 the north traffic light
     * @param t the decorator representing the north traffic light
     */
    public void setNorthTrafficLightDecorator(TrafficLightDecorator t) {
        northLight = t;
    }

    /**
     * Sets the west traffic light decorator for this intersection to represent
the west traffic light
     * @param t the decorator representing the west traffic light
     */
    public void setWestTrafficLightDecorator(TrafficLightDecorator t) {
        westLight = t;
    }

    /**
     * Sets the south traffic light decorator for this intersection to represent
 the south traffic light
     * @param t the decorator representing the south traffic light
     */
    public void setSouthTrafficLightDecorator(TrafficLightDecorator t) {
        southLight = t;
    }

    /**
     * Sets the east traffic light decorator for this intersection to represent
the east traffic light
     * @param t the decorator representing the east traffic light
     */
    public void setEastTrafficLightDecorator(TrafficLightDecorator t) {
        eastLight = t;
    }

    /**
     * Draws the intersection to display it in the GUI. It initializes all Traff
icLightDecorators as well, to make
     * them display properly.
     * @return the StackPane to represent this intersection
     */
    public StackPane drawIntersection() {
        StackPane stackPane = new StackPane();

        String roadBackgroundPath = "IntersectionX.png";
        Image image = new Image(roadBackgroundPath);
        Image im = new Image(roadBackgroundPath, image.getHeight() * resizeFacto
r.getResizeX(), image.getWidth() * resizeFactor.getResizeY(), false, true);
        ImageView iv = new ImageView(im);
        Pane lights = new Pane();
        double middleCoordX = 50*resizeFactor.getResizeX();
        double middleCoordY = 50*resizeFactor.getResizeY();
        double edgeCloseX = 18*resizeFactor.getResizeX();
        double edgeCloseY = 18*resizeFactor.getResizeY();
        double edgeFarX = 82*resizeFactor.getResizeX();
        double edgeFarY = 82*resizeFactor.getResizeY();
        double radius = 15*resizeFactor.getResizeX();
        if(intersection.getNorthTrafficLight() != null) {
            northLight = new TrafficLightDecorator(intersection.getNorthTrafficL
ight());
            northLight.drawLight(middleCoordX,edgeCloseY,radius);
            lights.getChildren().add(northLight.getCircle());
        }
        if(intersection.getEastTrafficLight() != null) {
            eastLight = new TrafficLightDecorator(intersection.getEastTrafficLig
ht());
            eastLight.drawLight(edgeFarX,middleCoordY,radius);
            lights.getChildren().add(eastLight.getCircle());
        }
        if(intersection.getSouthTrafficLight() != null) {
            southLight = new TrafficLightDecorator(intersection.getSouthTrafficL
ight());
            southLight.drawLight(middleCoordX,edgeFarY,radius);
            lights.getChildren().add(southLight.getCircle());
        }
        if(intersection.getWestTrafficLight() != null) {
            westLight = new TrafficLightDecorator(intersection.getWestTrafficLig
ht());
            westLight.drawLight(edgeCloseX,middleCoordY,radius);
            lights.getChildren().add(westLight.getCircle());
        }

        stackPane.getChildren().add(iv);
        stackPane.getChildren().add(lights);
        return stackPane;
    }

    /**
     * This method is only for DEBUG and TESTING! Displays the intersection in t
he given stack pane
     * @param stage the Stage to display this Intersection in
     */
    public void showIntersection(Stage stage, StackPane s) {
        root = new Group();
        scene = new Scene(root, width, height, Color.BEIGE);
        root.getChildren().add(s);
        stage.setScene(scene);
        stage.show();
    }

}
```

```java
package londonsw.view.simulation;

import javafx.scene.Group;
import javafx.scene.paint.Color;
import javafx.scene.shape.Line;
import javafx.scene.shape.Polygon;
import londonsw.model.simulation.components.Lane;
import londonsw.model.simulation.components.ResizeFactor;

/**
 * Created by felix on 16/03/2016.
 */
public class LaneArrow extends Polygon {

    protected Lane lane;

    public Group getGroup() {
        return group;
    }

    public void setGroup(Group group) {
        this.group = group;
    }

    private Group group;

    public LaneArrow(Lane lane, Line roadLine, ResizeFactor resizeFactor) {
        this.lane = lane;

        double arrowResizeFactor = resizeFactor.getResizeX() * 2.5;

        this.getPoints().addAll(
                0.0 * arrowResizeFactor, 5.0 * arrowResizeFactor,
                −5.0 * arrowResizeFactor, −5.0 * arrowResizeFactor,
                5.0 * arrowResizeFactor, −5.0 * arrowResizeFactor
        );


        roadLine.setStrokeWidth(2 * resizeFactor.getResizeY()); //TODO avoid har
dcode

        roadLine.setStrokeWidth(2 * resizeFactor.getResizeY()); //TODO avoid har
dcode

        if (lane.getState() == 1) {
            roadLine.setStroke(Color.WHITE);
            this.setFill(Color.WHITE);
        } else {
            //lane not enabled
            roadLine.setStroke(Color.RED);
            this.setFill(Color.RED);
        }

        double angle = 0.0;

        switch (lane.getMovingDirection())
        {
            case NORTH:
                angle = −90;
                this.setTranslateY(roadLine.getStartY());
                this.setTranslateX(roadLine.getStartX());
                break;
            case SOUTH:
                angle = 90;
                this.setTranslateY(roadLine.getEndY());
                this.setTranslateX(roadLine.getEndX());
                break;
            case EAST:
                angle = 0.0;
                this.setTranslateY(roadLine.getEndY());
                this.setTranslateX(roadLine.getEndX());
                break;
            case WEST:
                angle = 180;
                this.setTranslateY(roadLine.getStartY());
                this.setTranslateX(roadLine.getStartX());
                break;
        }

        this.setRotate(angle - 90);
        //roadLine.setRotate(angle - 90);

        Group group = new Group();

        group.getChildren().addAll(roadLine,this);

        //group.setRotate(angle - 90);

        this.setGroup(group);

    }
}
```

```java
package londonsw.view.simulation;

import javafx.scene.image.Image;
import javafx.scene.image.ImageView;
import javafx.scene.layout.StackPane;
import londonsw.model.simulation.components.ResizeFactor;

/**
 * This class provides the basis for drawing map components to the GUI screen
 */
public class LayoutGUI {

    private int height;
    private int width;
    private ResizeFactor resizeFactor;

    /**
     * Gets the resize factor for the GUI square
     * @return the resize factor for this square
     */
    public ResizeFactor getResizeFactor() {
        return resizeFactor;
    }

    /**
     * Sets the resize factor for this GUI square
     * @param resizeFactor the resize factor to set for this square
     */
    public void setResizeFactor(ResizeFactor resizeFactor) {
        this.resizeFactor = resizeFactor;
    }

    /**
     * Sets the width of this GUI square
     * @param width the width to set for this GUI square
     */
    public void setWidth(int width) {
        this.width = width;
    }

    /**
     * Sets the height of this GUI square
     * @param height the height to set for this GUI square
     */
    public void setHeight(int height) {
        this.height = height;
    }

    /**
     * This method gets called to draw a Grass square in the map, i.e. when ther
e is no other map component there,
     * it will look like grass
     * @return the StackPane representing grass
     */
    public StackPane drawGrass() {
        return drawLayout("Grass.png");
    }

    /**
```

```
     * The generic function that gets called by any map component drawing functi
on. It draws the map component given
     * a path to an image.
     * @param path the path to the image for this GUI square
     * @return the StackPane representing this GUI square, based on the provided
 image
     */
    private StackPane drawLayout(String path) {
        Image image = new Image(path);

        Image im  = new Image(path,image.getWidth()*this.getResizeFactor().getRe
sizeX(),image.getHeight()*this.getResizeFactor().getResizeY(),false,false);

        ImageView iv = new ImageView(im);

        StackPane stackPane = new StackPane();

        stackPane.getChildren().add(iv);

        return stackPane;
    }
}
```

```
package londonsw.view.simulation;

/**
 * Created by felix on 12/03/2016.
 */

import londonsw.model.simulation.Map;
import londonsw.model.simulation.components.*;

/**
 * Created by felix on 12/03/2016.
 */
public class MapExamples {



    public static Map drawMap1() throws Exception {
        Map map = new Map(15,15);

        Road r1 = new Road(new Coordinate(2,1),new Coordinate(10,1));
        Road r2 = new Road(new Coordinate(2,10),new Coordinate(10,10));
        Road r3 = new Road(new Coordinate(1,2), new Coordinate(1,9));
        Road r4 = new Road(new Coordinate(11,2), new Coordinate(11,9));
        Road rExit = new Road(new Coordinate(12,1), new Coordinate(12,1));

        Road roadMatrix[] = {r1,r2,r3,r4 , rExit};

        Lane laneR1L1 = new Lane(r1.getStartLocation(),r1.getEndLocation(), MapD
irection.EAST);
        Lane laneR1L2 = new Lane(r1.getStartLocation(),r1.getEndLocation(), MapD
irection.EAST);
        Lane laneR1L3 = new Lane(r1.getEndLocation(),r1.getStartLocation(), MapD
irection.WEST);
        Lane laneR1L4 = new Lane(r1.getEndLocation(),r1.getStartLocation(), MapD
irection.WEST);

        Lane laneR2L1 = new Lane(r2.getStartLocation(),r2.getEndLocation(), MapD
irection.EAST);
        Lane laneR2L2 = new Lane(r2.getStartLocation(),r2.getEndLocation(), MapD
irection.EAST);
        Lane laneR2L3 = new Lane(r2.getEndLocation(),r2.getStartLocation(), MapD
irection.WEST);
        Lane laneR2L4 = new Lane(r2.getEndLocation(),r2.getStartLocation(), MapD
irection.WEST);

        Lane laneR3L1 = new Lane(r3.getEndLocation(),r3.getStartLocation(), MapD
irection.NORTH);
        Lane laneR3L2 = new Lane(r3.getEndLocation(),r3.getStartLocation(), MapD
irection.NORTH);
        Lane laneR3L3 = new Lane(r3.getStartLocation(),r3.getEndLocation(), MapD
irection.SOUTH);
        Lane laneR3L4 = new Lane(r3.getStartLocation(),r3.getEndLocation(), MapD
irection.SOUTH);

        Lane laneR4L1 = new Lane(r4.getEndLocation(),r4.getStartLocation(), MapD
irection.NORTH);
        Lane laneR4L2 = new Lane(r4.getEndLocation(),r4.getStartLocation(), MapD
irection.NORTH);
        Lane laneR4L3 = new Lane(r4.getStartLocation(),r4.getEndLocation(), MapD
irection.SOUTH);
        Lane laneR4L4 = new Lane(r4.getStartLocation(),r4.getEndLocation(), MapD
irection.SOUTH);

        Lane laneExitL1 = new Lane(rExit.getStartLocation(),rExit.getEndLocation
(),MapDirection.EAST);

        r1.addLane(laneR1L1);
        //r1.addLane(laneR1L2);
        //r1.addLane(laneR1L3);
        r1.addLane(laneR1L4);

        r2.addLane(laneR2L1);
        //r2.addLane(laneR2L2);
        //r2.addLane(laneR2L3);
        r2.addLane(laneR2L4);

        r3.addLane(laneR3L1);
        //r3.addLane(laneR3L2);
        //r3.addLane(laneR3L3);
        r3.addLane(laneR3L4);

        //laneR4L3.setState(0);
        //laneR4L4.setState(0);

        r4.addLane(laneR4L1);
        //r4.addLane(laneR4L2);
        //r4.addLane(laneR4L3);
        r4.addLane(laneR4L4);

        rExit.addLane(laneExitL1);

        for(int i = 0 ; i < roadMatrix.length; i++)
            map.addRoad(roadMatrix[i]);

        Intersection i1 = new Intersection(new Coordinate(1,1));
        i1.setEastRoad(r1);
        i1.setSouthRoad(r3);


        i1.setDefaultTrafficLightsForRoads();

        Intersection i2 = new Intersection(new Coordinate(11,1));
        i2.setWestRoad(r1);
        i2.setSouthRoad(r4);
        i2.setEastRoad(rExit);
        i2.setDefaultTrafficLightsForRoads();

        Intersection i3 = new Intersection(new Coordinate(1,10));
        i3.setEastRoad(r2);
        i3.setNorthRoad(r3);
        i3.setDefaultTrafficLightsForRoads();

        Intersection i4 = new Intersection(new Coordinate(11,10));

        i4.setWestRoad(r2);
        i4.setNorthRoad(r4);
        i4.setDefaultTrafficLightsForRoads();
        map.addIntersection(i1);
        map.addIntersection(i2);
        map.addIntersection(i3);
        map.addIntersection(i4);

        return  map;
    }

    public static Map drawMap1_1() throws Exception{

        Map map = new Map(6,6);

        Road R1 = new Road(new Coordinate(1,1),new Coordinate(4,1));

        Lane laneR1L1 = new Lane(R1.getStartLocation(),R1.getEndLocation(),MapDi
rection.EAST);

        R1.addLane(laneR1L1);

        map.addRoad(R1);

        return map;

    }


    public static Map dratMap4 () throws Exception {

        Map map = new Map(22, 22);

        Road r04 = new Road(new Coordinate(1, 11), new Coordinate(1, 14));
        Road r08 = new Road(new Coordinate(20, 11), new Coordinate(20, 14));
        Road r09 = new Road(new Coordinate(9, 15), new Coordinate(19, 15));
        Road r10 = new Road(new Coordinate(2, 15), new Coordinate(7, 15));
        Road r13 = new Road(new Coordinate(2, 10), new Coordinate(7, 10));
        Road r14 = new Road(new Coordinate(9, 10), new Coordinate(12, 10));
        Road r15 = new Road(new Coordinate(14, 10), new Coordinate(19, 10));
        Road r16 = new Road(new Coordinate(8, 11), new Coordinate(8, 14));
        Road r20 = new Road(new Coordinate(1, 16), new Coordinate(1, 19));
        Road r21 = new Road(new Coordinate(8, 16), new Coordinate(8, 19));
        Road r22 = new Road(new Coordinate(2, 20), new Coordinate(7, 20));
        Road r23 = new Road(new Coordinate(9, 20), new Coordinate(19, 20));
        Road r24 = new Road(new Coordinate(20, 16), new Coordinate(20, 19));

        /*This is a one lane Map
        If you want two lanes map
        comment these Lines , and uncomment The two lane code
        at the bottom
         */

/*
        r01.addLane(new Lane(r01.getStartLocation(),r01.getEndLocation(),MapDire
ction.EAST));
        r02.addLane(new Lane (r02.getEndLocation(),r02.getStartLocation(),MapDir
ection.NORTH));
        r03.addLane(new Lane(r03.getEndLocation(),r03.getStartLocation(),MapDire
ction.NORTH));
        r04.addLane(new Lane(r04.getEndLocation(),r04.getStartLocation(),MapDire
ction.NORTH));
        Lane l5 = new Lane(r05.getStartLocation(),r05.getEndLocation(),MapDirect
ion.EAST);
        //l5.setState(0);
        r05.addLane(l5);
        Lane l6 = new Lane(r06.getStartLocation(),r06.getEndLocation(),MapDirect
ion.EAST);
        r06.addLane(l6);
        //l6.setState(0);
        r07.addLane(new Lane(r07.getStartLocation(),r07.getEndLocation(),MapDire
ction.SOUTH));
        r08.addLane(new Lane(r08.getStartLocation(),r08.getEndLocation(),MapDire
ction.SOUTH));
        r09.addLane(new Lane(r09.getEndLocation(),r09.getStartLocation(),MapDire
ction.WEST));
        r10.addLane(new Lane(r10.getEndLocation(),r10.getStartLocation(),MapDire
ction.WEST));
        r11.addLane(new Lane(r11.getEndLocation(),r11.getStartLocation(),MapDire
ction.NORTH));
        r12.addLane(new Lane(r12.getStartLocation(),r12.getEndLocation(),MapDire
ction.EAST));
        r13.addLane(new Lane(r13.getStartLocation(),r13.getEndLocation(),MapDire
ction.EAST));
        r14.addLane(new Lane(r14.getStartLocation(),r14.getEndLocation(),MapDire
ction.EAST));
        r15.addLane(new Lane(r15.getStartLocation(),r15.getEndLocation(),MapDire
ction.EAST));
        r16.addLane(new Lane(r16.getEndLocation(),r16.getStartLocation(),MapDire
ction.NORTH));
        r17.addLane(new Lane(r17.getEndLocation(),r17.getStartLocation(),MapDire
ction.NORTH));
        r18.addLane(new Lane(r18.getEndLocation(),r18.getStartLocation(),MapDire
ction.NORTH));
        r19.addLane(new Lane(r19.getStartLocation(),r19.getEndLocation(),MapDire
ction.EAST));
        r20.addLane(new Lane(r20.getEndLocation(),r20.getStartLocation(),MapDire
ction.NORTH));
        r21.addLane(new Lane(r21.getEndLocation(),r21.getStartLocation(),MapDire
ction.NORTH));
        r22.addLane(new Lane(r22.getEndLocation(),r22.getStartLocation(),MapDire
ction.WEST));
        r23.addLane(new Lane(r23.getEndLocation(),r23.getStartLocation(),MapDire
ction.WEST));
        r24.addLane(new Lane(r24.getStartLocation(),r24.getEndLocation(),MapDire
ction.SOUTH));
*/

          /*This is a two lane Map
        If you want one lanes map
        comment these Lines , and uncomment The one lane code above
         */



        r04.addLane(new Lane(r04.getEndLocation(), r04.getStartLocation(), MapDi
rection.NORTH));
        r08.addLane(new Lane(r08.getEndLocation(), r08.getStartLocation(), MapDi
rection.NORTH));
        Lane l9=new Lane(r09.getStartLocation(), r09.getEndLocation(), MapDirect
ion.EAST);
         l9.setState(0);
        r09.addLane(l9);
        r10.addLane(new Lane(r10.getStartLocation(), r10.getEndLocation(), MapDi
rection.EAST));
        r13.addLane(new Lane(r13.getStartLocation(), r13.getEndLocation(), MapDi
rection.EAST));
        r14.addLane(new Lane(r14.getStartLocation(), r14.getEndLocation(), MapDi
rection.EAST));
        r15.addLane(new Lane(r15.getStartLocation(), r15.getEndLocation(), MapDi
rection.EAST));
        Lane l16 =new Lane(r16.getEndLocation(), r16.getStartLocation(), MapDire
ction.NORTH);
        l16.setState(0);
        r16.addLane(l16);
        r20.addLane(new Lane(r20.getEndLocation(), r20.getStartLocation(), MapDi
rection.NORTH));
        r21.addLane(new Lane(r21.getEndLocation(), r21.getStartLocation(), MapDi
rection.NORTH));
        r22.addLane(new Lane(r22.getStartLocation(), r22.getEndLocation(), MapDi
rection.EAST));
        r23.addLane(new Lane(r23.getStartLocation(), r23.getEndLocation(), MapDi
rection.EAST));
        r24.addLane(new Lane(r24.getEndLocation(), r24.getStartLocation(), MapDi
rection.NORTH));


        r04.addLane(new Lane(r04.getStartLocation(), r04.getEndLocation(), MapDi
rection.SOUTH));
        r08.addLane(new Lane(r08.getStartLocation(), r08.getEndLocation(), MapDi
rection.SOUTH));
        r09.addLane(new Lane(r09.getEndLocation(), r09.getStartLocation(), MapDi
rection.WEST));
        Lane l10=new Lane(r10.getEndLocation(), r10.getStartLocation(), MapDirec
tion.WEST);
        l10.setState(0);
        r10.addLane(l10);
        r13.addLane(new Lane(r13.getEndLocation(), r13.getStartLocation(), MapDi
rection.WEST));
        r14.addLane(new Lane(r14.getEndLocation(), r14.getStartLocation(), MapDi
rection.WEST));
        r15.addLane(new Lane(r15.getEndLocation(), r15.getStartLocation(), MapDi
rection.WEST));
        r16.addLane(new Lane(r16.getStartLocation(), r16.getEndLocation(), MapDi
rection.SOUTH));
        r20.addLane(new Lane(r20.getStartLocation(), r20.getEndLocation(), MapDi
rection.SOUTH));
        Lane l21=new Lane(r21.getStartLocation(), r21.getEndLocation(), MapDirec
tion.SOUTH);
        l21.setState(0);
        r21.addLane(l21);
        r22.addLane(new Lane(r22.getEndLocation(), r22.getStartLocation(), MapDi
rection.WEST));
        r23.addLane(new Lane(r23.getEndLocation(), r23.getStartLocation(), MapDi
rection.WEST));
        r24.addLane(new Lane(r24.getStartLocation(), r24.getEndLocation(), MapDi
rection.SOUTH));
```

```
        Intersection i03 = new Intersection(new Coordinate(1, 10));
        i03.setSouthRoad(r04);
        i03.setEastRoad(r13);
        //i03.setDefaultTrafficLightsForRoads();

        Intersection i04 = new Intersection(new Coordinate(1, 15));
        i04.setNorthRoad(r04);
        i04.setEastRoad(r10);
        i04.setSouthRoad(r20);
       // i04.setDefaultTrafficLightsForRoads();


        Intersection i08 = new Intersection(new Coordinate(20, 10));
        i08.setSouthRoad(r08);
        i08.setWestRoad(r15);
       // i08.setDefaultTrafficLightsForRoads();

        Intersection i09 = new Intersection(new Coordinate(20, 15));
        i09.setNorthRoad(r08);
        i09.setWestRoad(r09);
        i09.setSouthRoad(r24);
        //i09.setDefaultTrafficLightsForRoads();

        Intersection i10 = new Intersection(new Coordinate(8, 15));
        i10.setEastRoad(r09);
        i10.setWestRoad(r10);
        i10.setNorthRoad(r16);
        i10.setSouthRoad(r21);
        i10.setDefaultTrafficLightsForRoads();


        Intersection i12 = new Intersection(new Coordinate(8, 10));
        i12.setWestRoad(r13);
        i12.setEastRoad(r14);
        i12.setSouthRoad(r16);
       // i12.setDefaultTrafficLightsForRoads();

        Intersection i13 = new Intersection(new Coordinate(13, 10));
        i13.setWestRoad(r14);
        i13.setEastRoad(r15);
       // i13.setDefaultTrafficLightsForRoads();

        Intersection i15 = new Intersection(new Coordinate(1, 20));
        i15.setNorthRoad(r20);
        i15.setEastRoad(r22);
       // i15.setDefaultTrafficLightsForRoads();

        Intersection i16 = new Intersection(new Coordinate(8, 20));
        i16.setWestRoad(r22);
        i16.setNorthRoad(r21);
        i16.setEastRoad(r23);
       // i16.setDefaultTrafficLightsForRoads();

        Intersection i17 = new Intersection(new Coordinate(20, 20));
        i17.setWestRoad(r23);
        i17.setNorthRoad(r24);
        //i17.setDefaultTrafficLightsForRoads();
        map.addRoad(r04);
        map.addRoad(r08);
        map.addRoad(r09);
        map.addRoad(r10);
        map.addRoad(r13);
        map.addRoad(r14);
        map.addRoad(r15);
        map.addRoad(r16);
        map.addRoad(r20);
        map.addRoad(r21);
        map.addRoad(r22);
        map.addRoad(r23);
        map.addRoad(r24);


        map.addIntersection(i03);
        map.addIntersection(i04);
        map.addIntersection(i08);
        map.addIntersection(i09);
        map.addIntersection(i10);
        map.addIntersection(i12);
        map.addIntersection(i13);
        map.addIntersection(i15);
        map.addIntersection(i16);
        map.addIntersection(i17);

        return map;


    }


    public static Map drawTestMapBasic() throws Exception {

        Map map = new Map(10, 10);

        Road r1 = new Road(new Coordinate(2, 1), new Coordinate(8, 1));
        Road r2 = new Road(new Coordinate(1, 2), new Coordinate(1, 8));
        Road r3 = new Road(new Coordinate(9, 2), new Coordinate(9, 8));
        Road r4 = new Road(new Coordinate(2, 9), new Coordinate(8, 9));

        r1.addLane(new Lane(r1.getStartLocation(), r1.getEndLocation(), MapDirec
tion.EAST));

        r2.addLane(new Lane(r2.getEndLocation(), r2.getStartLocation(), MapDirec
tion.NORTH));

        r3.addLane(new Lane(r3.getStartLocation(), r3.getEndLocation(), MapDirec
tion.SOUTH));

        r4.addLane(new Lane(r4.getEndLocation(), r4.getStartLocation(), MapDirec
tion.WEST));

        map.addRoad(r1);
        map.addRoad(r2);
```

```java
        map.addRoad(r3);
        map.addRoad(r4);

        Intersection i1 = new Intersection(new Coordinate(1, 1));
        i1.setEastRoad(r1);
        i1.setSouthRoad(r2);

        Intersection i2 = new Intersection(new Coordinate(9, 1));
        i2.setWestRoad(r1);
        i2.setSouthRoad(r3);
        Intersection i3 = new Intersection(new Coordinate(1, 9));
        i3.setNorthRoad(r2);
        i3.setEastRoad(r4);
        Intersection i4 = new Intersection(new Coordinate(9, 9));
        i4.setNorthRoad(r3);
        i4.setWestRoad(r4);

        map.addIntersection(i1);
        map.addIntersection(i2);
        map.addIntersection(i3);
        map.addIntersection(i4);

        return map;
    }

    public static Map drawTestMapSingleLine() throws Exception {

        Map map = new Map(25, 25);

        Road r1 = new Road(new Coordinate(2, 1), new Coordinate(8, 1));
        Road r2 = new Road(new Coordinate(1, 2), new Coordinate(1, 8));
        Road r3 = new Road(new Coordinate(9, 2), new Coordinate(9, 8));
        Road r4 = new Road(new Coordinate(2, 9), new Coordinate(8, 9));

        Road r5 = new Road(new Coordinate(10, 1), new Coordinate(16, 1));
        Road r6 = new Road(new Coordinate(17, 2), new Coordinate(17, 8));
        Road r7 = new Road(new Coordinate(10, 9), new Coordinate(16, 9));

        Lane disabledLane = new Lane(r3.getStartLocation(), r3.getEndLocation(),
 MapDirection.SOUTH);

        //disable lane
        disabledLane.setState(0);

        r1.addLane(new Lane(r1.getStartLocation(), r1.getEndLocation(), MapDirec
tion.EAST));

        r2.addLane(new Lane(r2.getEndLocation(), r2.getStartLocation(), MapDirec
tion.NORTH));

        r3.addLane(disabledLane);

        r4.addLane(new Lane(r4.getEndLocation(), r4.getStartLocation(), MapDirec
tion.WEST));

        r5.addLane(new Lane(r5.getStartLocation(), r5.getEndLocation(), MapDirec
tion.EAST));

        r6.addLane(new Lane(r6.getStartLocation(), r6.getEndLocation(), MapDirec
tion.SOUTH));

        r7.addLane(new Lane(r7.getEndLocation(), r7.getStartLocation(), MapDirec
tion.WEST));

        map.addRoad(r1);
        map.addRoad(r2);
        map.addRoad(r3);
        map.addRoad(r4);
        map.addRoad(r5);
        map.addRoad(r6);
        map.addRoad(r7);

        Intersection i1 = new Intersection(new Coordinate(1, 1));
        i1.setEastRoad(r1);
        i1.setSouthRoad(r2);

        Intersection i2 = new Intersection(new Coordinate(9, 1));
        i2.setWestRoad(r1);
        i2.setSouthRoad(r3);
        i2.setEastRoad(r5);

        Intersection i3 = new Intersection(new Coordinate(1, 9));
        i3.setNorthRoad(r2);
        i3.setEastRoad(r4);

        Intersection i4 = new Intersection(new Coordinate(9, 9));
        i4.setNorthRoad(r3);
        i4.setWestRoad(r4);
        i4.setEastRoad(r7);

        Intersection i5 = new Intersection(new Coordinate(17, 1));
        i5.setWestRoad(r5);
        i5.setSouthRoad(r6);

        Intersection i6 = new Intersection(new Coordinate(17, 9));
        i6.setNorthRoad(r6);
        i6.setWestRoad(r7);

        map.addIntersection(i1);
        map.addIntersection(i2);
        map.addIntersection(i3);
        map.addIntersection(i4);
        map.addIntersection(i5);
        map.addIntersection(i6);

        return map;
    }



    public static Map drawTestMapSimple() throws Exception {

        Map map = new Map(10,10);

        Road r1 = new Road(new Coordinate(2,1), new Coordinate(8,1));
        Road r2 = new Road(new Coordinate(1,2), new Coordinate(1,8));
        Road r3 = new Road(new Coordinate(9,2), new Coordinate(9,8));
        Road r4 = new Road(new Coordinate(2,9), new Coordinate(8,9));
        r1.addLane(new Lane(r1.getStartLocation(),r1.getEndLocation(), MapDirect
ion.EAST));
        r1.addLane(new Lane(r1.getEndLocation() ,r1.getStartLocation(), MapDirec
tion.WEST));

        r2.addLane(new Lane(r2.getEndLocation(),r2.getStartLocation(), MapDirect
ion.NORTH));
        r2.addLane(new Lane(r2.getStartLocation(),r2.getEndLocation(), MapDirect
ion.SOUTH));

        r3.addLane(new Lane(r3.getEndLocation(),r3.getStartLocation(), MapDirect
ion.NORTH));
        r3.addLane(new Lane(r3.getStartLocation(),r3.getEndLocation(), MapDirect
ion.SOUTH));

        r4.addLane(new Lane(r4.getStartLocation(),r4.getEndLocation(), MapDirect
ion.EAST));
        r4.addLane(new Lane(r4.getEndLocation(),r4.getStartLocation(), MapDirect
ion.WEST));

        map.addRoad(r1);
        map.addRoad(r2);
        map.addRoad(r3);
        map.addRoad(r4);

        Intersection i1 = new Intersection(new Coordinate(1,1));
        i1.setEastRoad(r1);
        i1.setSouthRoad(r2);

        Intersection i2 = new Intersection(new Coordinate(9,1));
        i2.setWestRoad(r1);
        i2.setSouthRoad(r3);
        Intersection i3 = new Intersection(new Coordinate(1,9));
        i3.setNorthRoad(r2);
        i3.setEastRoad(r4);
        Intersection i4 = new Intersection(new Coordinate(9,9));
        i4.setNorthRoad(r3);
        i4.setWestRoad(r4);

        map.addIntersection(i1);
        map.addIntersection(i2);
        map.addIntersection(i3);
        map.addIntersection(i4);

        return map;
    }

    public static Map drawTestMapBig() throws Exception {

        Map map = new Map(20,20);

        Road r1 = new Road(new Coordinate(2,1), new Coordinate(8,1));
        Road r2 = new Road(new Coordinate(1,2), new Coordinate(1,8));
        Road r3 = new Road(new Coordinate(9,2), new Coordinate(9,8));
        Road r4 = new Road(new Coordinate(2,9), new Coordinate(8,9));
        Road r5 = new Road(new Coordinate(10,1), new Coordinate(16,1));
        Road r6 = new Road(new Coordinate(17,2), new Coordinate(17,8));
        Road r7 = new Road(new Coordinate(10,9), new Coordinate(16,9));

        Lane disabledLane = new Lane(r3.getStartLocation(),r3.getEndLocation(),
MapDirection.SOUTH);

        //disable lane
        disabledLane.setState(0);

        r1.addLane(new Lane(r1.getStartLocation(),r1.getEndLocation(), MapDirect
ion.EAST));
        r1.addLane(new Lane(r1.getEndLocation() ,r1.getStartLocation(), MapDirec
tion.WEST));

        r2.addLane(new Lane(r2.getEndLocation(),r2.getStartLocation(), MapDirect
ion.NORTH));
        r2.addLane(new Lane(r2.getStartLocation(),r2.getEndLocation(), MapDirect
ion.SOUTH));

        r3.addLane(new Lane(r3.getEndLocation(),r3.getStartLocation(), MapDirect
ion.NORTH));
        r3.addLane(disabledLane);

        r4.addLane(new Lane(r4.getStartLocation(),r4.getEndLocation(), MapDirect
ion.EAST));
        r4.addLane(new Lane(r4.getEndLocation(),r4.getStartLocation(), MapDirect
ion.WEST));

        r5.addLane(new Lane(r5.getStartLocation(),r5.getEndLocation(), MapDirect
ion.EAST));
        r5.addLane(new Lane(r5.getEndLocation(),r5.getStartLocation(), MapDirect
ion.WEST));

        r6.addLane(new Lane(r6.getEndLocation(),r6.getStartLocation(), MapDirect
ion.NORTH));
        r6.addLane(new Lane(r6.getStartLocation(),r6.getEndLocation(), MapDirect
ion.SOUTH));

        r7.addLane(new Lane(r7.getStartLocation(),r7.getEndLocation(), MapDirect
ion.EAST));
        r7.addLane(new Lane(r7.getEndLocation(),r7.getStartLocation(), MapDirect
ion.WEST));

        map.addRoad(r1);
        map.addRoad(r2);
        map.addRoad(r3);
        map.addRoad(r4);
        map.addRoad(r5);
        map.addRoad(r6);
        map.addRoad(r7);

        Intersection i1 = new Intersection(new Coordinate(1,1));
        i1.setEastRoad(r1);
        i1.setSouthRoad(r2);

        Intersection i2 = new Intersection(new Coordinate(9,1));
        i2.setWestRoad(r1);
        i2.setSouthRoad(r3);
        i2.setEastRoad(r5);

        Intersection i3 = new Intersection(new Coordinate(1,9));
        i3.setNorthRoad(r2);
        i3.setEastRoad(r4);

        Intersection i4 = new Intersection(new Coordinate(9,9));
        i4.setNorthRoad(r3);
        i4.setWestRoad(r4);
        i4.setEastRoad(r7);

        Intersection i5 = new Intersection(new Coordinate(17,1));
        i5.setWestRoad(r5);
        i5.setSouthRoad(r6);

        Intersection i6 = new Intersection(new Coordinate(17,9));
        i6.setNorthRoad(r6);
        i6.setWestRoad(r7);

        map.addIntersection(i1);
        map.addIntersection(i2);
        map.addIntersection(i3);
        map.addIntersection(i4);
        map.addIntersection(i5);
        map.addIntersection(i6);

        return map;
    }

    //Added new Map with two lanes
    public static Map drawTestMapExample() throws Exception {

        Map map = new Map(22,22);

        Road r01 = new Road(new Coordinate(2,1), new Coordinate(4,1));
        Road r02 = new Road(new Coordinate(1,2), new Coordinate(1,4));
        Road r03 = new Road(new Coordinate(1,6), new Coordinate(1,9));
        Road r04 = new Road(new Coordinate(1,11), new Coordinate(1,14));
        Road r05 = new Road(new Coordinate(6,1), new Coordinate(12,1));
        Road r06 = new Road(new Coordinate(14,1), new Coordinate(19,1));
        Road r07 = new Road(new Coordinate(20,2), new Coordinate(20,9));
        Road r08 = new Road(new Coordinate(20,11), new Coordinate(20,14));
        Road r09 = new Road(new Coordinate(9,15), new Coordinate(19,15));
        Road r10 = new Road(new Coordinate(2,15), new Coordinate(7,15));
        Road r11 = new Road(new Coordinate(5,2), new Coordinate(5,4));
        Road r12 = new Road(new Coordinate(2,5), new Coordinate(4,5));
        Road r13 = new Road(new Coordinate(2,10), new Coordinate(7,10));
        Road r14 = new Road(new Coordinate(9,10), new Coordinate(12,10));
        Road r15 = new Road(new Coordinate(14,10), new Coordinate(19,10));
        Road r16 = new Road(new Coordinate(8,11), new Coordinate(8,14));
        Road r17 = new Road(new Coordinate(13,2), new Coordinate(13,4));
        Road r18 = new Road(new Coordinate(13,6), new Coordinate(13,9));
        Road r19 = new Road(new Coordinate(6,5),new Coordinate(12,5));
        Road r20 = new Road(new Coordinate(1,16),new Coordinate(1,19));
        Road r21 = new Road(new Coordinate(8,16),new Coordinate(8,19));
        Road r22 = new Road(new Coordinate(2,20),new Coordinate(7,20));
        Road r23 = new Road(new Coordinate(9,20),new Coordinate(19,20));
        Road r24 = new Road(new Coordinate(20,16), new Coordinate(20,19));
        r01.addLane(new Lane(r01.getStartLocation(),r01.getEndLocation(),MapDire
ction.EAST));
        r02.addLane(new Lane (r02.getEndLocation(),r02.getStartLocation(),MapDir
ection.NORTH));
        r03.addLane(new Lane(r03.getEndLocation(),r03.getStartLocation(),MapDire
ction.NORTH));
        r04.addLane(new Lane(r04.getEndLocation(),r04.getStartLocation(),MapDire
ction.NORTH));
        Lane l5 = new Lane(r05.getStartLocation(),r05.getEndLocation(),MapDirect
ion.EAST);
        //l5.setState(0);
        r05.addLane(l5);
        Lane l6 = new Lane(r06.getStartLocation(),r06.getEndLocation(),MapDirect
ion.EAST);
        r06.addLane(l6);
        //l6.setState(0);
        r07.addLane(new Lane(r07.getEndLocation(),r07.getStartLocation(),MapDire
ction.NORTH));
        r08.addLane(new Lane(r08.getEndLocation(),r08.getStartLocation(),MapDire
ction.NORTH));

        Lane lane9Closed = new Lane(r09.getStartLocation(),r09.getEndLocation(),
MapDirection.EAST);

        //lane9Closed.setState(0);

        r09.addLane(lane9Closed);


        r10.addLane(new Lane(r10.getStartLocation(),r10.getEndLocation(),MapDire
ction.EAST));
        r11.addLane(new Lane(r11.getEndLocation(),r11.getStartLocation(),MapDire
ction.NORTH));
        r12.addLane(new Lane(r12.getStartLocation(),r12.getEndLocation(),MapDire
ction.EAST));

        r13.addLane(new Lane(r13.getStartLocation(),r13.getEndLocation(),MapDire
ction.EAST));
        r14.addLane(new Lane(r14.getStartLocation(),r14.getEndLocation(),MapDire
ction.EAST));
        r15.addLane(new Lane(r15.getStartLocation(),r15.getEndLocation(),MapDire
ction.EAST));
        r16.addLane(new Lane(r16.getEndLocation(),r16.getStartLocation(),MapDire
ction.NORTH));
        r17.addLane(new Lane(r17.getEndLocation(),r17.getStartLocation(),MapDire
ction.NORTH));
        r18.addLane(new Lane(r18.getEndLocation(),r18.getStartLocation(),MapDire
ction.NORTH));
        r19.addLane(new Lane(r19.getStartLocation(),r19.getEndLocation(),MapDire
ction.EAST));
        r20.addLane(new Lane(r20.getEndLocation(),r20.getStartLocation(),MapDire
ction.NORTH));

        Lane lane21NClosed = new Lane(r21.getEndLocation(),r21.getStartLocation(
),MapDirection.NORTH);
        //lane21Closed.setState(0);

        r21.addLane(lane21NClosed);
        r22.addLane(new Lane(r22.getStartLocation(),r22.getEndLocation(),MapDire
ction.EAST));
        r23.addLane(new Lane(r23.getStartLocation(),r23.getEndLocation(),MapDire
ction.EAST));
        r24.addLane(new Lane(r24.getEndLocation(),r24.getStartLocation(),MapDire
ction.NORTH));


        r01.addLane(new Lane(r01.getEndLocation(),r01.getStartLocation(),MapDire
ction.WEST));
        r02.addLane(new Lane (r02.getStartLocation(),r02.getEndLocation(),MapDir
ection.SOUTH));
        r03.addLane(new Lane(r03.getStartLocation(),r03.getEndLocation(),MapDire
ction.SOUTH));
        r04.addLane(new Lane(r04.getStartLocation(),r04.getEndLocation(),MapDire
ction.SOUTH));
        r05.addLane(new Lane(r05.getEndLocation(),r05.getStartLocation(),MapDire
ction.WEST));
        r06.addLane(new Lane(r06.getEndLocation(),r06.getStartLocation(),MapDire
ction.WEST));
        r07.addLane(new Lane(r07.getStartLocation(),r07.getEndLocation(),MapDire
ction.SOUTH));
        r08.addLane(new Lane(r08.getStartLocation(),r08.getEndLocation(),MapDire
ction.SOUTH));
        r09.addLane(new Lane(r09.getEndLocation(),r09.getStartLocation(),MapDire
ction.WEST));
        r10.addLane(new Lane(r10.getEndLocation(),r10.getStartLocation(),MapDire
ction.WEST));
        r11.addLane(new Lane(r11.getStartLocation(),r11.getEndLocation(),MapDire
ction.SOUTH));
        r12.addLane(new Lane(r12.getEndLocation(),r12.getStartLocation(),MapDire
ction.WEST));

        Lane lane13WClosed = new Lane(r13.getEndLocation(),r13.getStartLocation(
),MapDirection.WEST);
        //lane13WClosed.setState(0);

        r13.addLane(lane13WClosed);
        r14.addLane(new Lane(r14.getEndLocation(),r14.getStartLocation(),MapDire
ction.WEST));
        r15.addLane(new Lane(r15.getEndLocation(),r15.getStartLocation(),MapDire
ction.WEST));
        r16.addLane(new Lane(r16.getStartLocation(),r16.getEndLocation(),MapDire
ction.SOUTH));
        r17.addLane(new Lane(r17.getStartLocation(),r17.getEndLocation(),MapDire
ction.SOUTH));
        r18.addLane(new Lane(r18.getStartLocation(),r18.getEndLocation(),MapDire
ction.SOUTH));
        r19.addLane(new Lane(r19.getEndLocation(),r19.getStartLocation(),MapDire
ction.WEST));
        r20.addLane(new Lane(r20.getStartLocation(),r20.getEndLocation(),MapDire
ction.SOUTH));

        Lane lane21SClosed = new Lane(r21.getStartLocation(),r21.getEndLocation(
),MapDirection.SOUTH);
        //lane21SClosed.setState(0);

        r21.addLane(lane21SClosed);
        r22.addLane(new Lane(r22.getEndLocation(),r22.getStartLocation(),MapDire
ction.WEST));
        r23.addLane(new Lane(r23.getEndLocation(),r23.getStartLocation(),MapDire
ction.WEST));
        r24.addLane(new Lane(r24.getStartLocation(),r24.getEndLocation(),MapDire
ction.SOUTH));


        Intersection i01 = new Intersection(new Coordinate(1,1));
        i01.setEastRoad(r01);
        i01.setSouthRoad(r02);
        i01.setDefaultTrafficLightsForRoads();

        Intersection i02 = new Intersection(new Coordinate(1,5));
        i02.setNorthRoad(r02);
        i02.setSouthRoad(r03);
        i02.setEastRoad(r12);
        i02.setDefaultTrafficLightsForRoads();

        Intersection i03 = new Intersection(new Coordinate(1,10));
        i03.setNorthRoad(r03);
        i03.setSouthRoad(r04);
        i03.setEastRoad(r13);
        i03.setDefaultTrafficLightsForRoads();

        Intersection i04 = new Intersection(new Coordinate(1,15));
        i04.setNorthRoad(r04);
        i04.setEastRoad(r10);
        i04.setSouthRoad(r20);
        i04.setDefaultTrafficLightsForRoads();

        Intersection i05 = new Intersection(new Coordinate(5,1));
        i05.setWestRoad(r01);
        i05.setEastRoad(r05);
        i05.setSouthRoad(r11);
        i05.setDefaultTrafficLightsForRoads();

        Intersection i06 = new Intersection(new Coordinate(13,1));
        i06.setWestRoad(r05);
        i06.setEastRoad(r06);
        i06.setSouthRoad(r17);
        i06.setDefaultTrafficLightsForRoads();

        Intersection i07 = new Intersection(new Coordinate(20,1));
        i07.setWestRoad(r06);
        i07.setSouthRoad(r07);
        i07.setDefaultTrafficLightsForRoads();

        Intersection i08 = new Intersection(new Coordinate(20,10));
        i08.setNorthRoad(r07);
        i08.setSouthRoad(r08);
        i08.setWestRoad(r15);
        i08.setDefaultTrafficLightsForRoads();

        Intersection i09 = new Intersection(new Coordinate(20,15));
        i09.setNorthRoad(r08);
        i09.setWestRoad(r09);
        i09.setSouthRoad(r24);
        i09.setDefaultTrafficLightsForRoads();
        Intersection i10 = new Intersection(new Coordinate(8,15));
        i10.setEastRoad(r09);
        i10.setWestRoad(r10);
        i10.setNorthRoad(r16);
        i10.setSouthRoad(r21);
        i10.setDefaultTrafficLightsForRoads();

        Intersection i11 = new Intersection(new Coordinate(5,5));
        i11.setWestRoad(r12);
        i11.setNorthRoad(r11);
        i11.setEastRoad(r19);
        i11.setDefaultTrafficLightsForRoads();

        Intersection i12 = new Intersection(new Coordinate(8,10));
        i12.setWestRoad(r13);
        i12.setEastRoad(r14);
        i12.setSouthRoad(r16);
        i12.setDefaultTrafficLightsForRoads();    //enables tl

        Intersection i13 = new Intersection(new Coordinate(13,10));
        i13.setWestRoad(r14);
        i13.setEastRoad(r15);
        i13.setNorthRoad(r18);
        i13.setDefaultTrafficLightsForRoads();

        Intersection i14 =new Intersection((new Coordinate(13,5)));
        i14.setNorthRoad(r17);
        i14.setSouthRoad(r18);
        i14.setWestRoad(r19);
        i14.setDefaultTrafficLightsForRoads();

        Intersection i15 =new Intersection(new Coordinate(1,20));
        i15.setNorthRoad(r20);
        i15.setEastRoad(r22);
        i15.setDefaultTrafficLightsForRoads();

        Intersection i16 =new Intersection(new Coordinate(8,20));
        i16.setWestRoad(r22);
        i16.setNorthRoad(r21);
        i16.setEastRoad(r23);
        i16.setDefaultTrafficLightsForRoads();

        Intersection i17= new Intersection (new Coordinate(20,20));
        i17.setWestRoad(r23);
        i17.setNorthRoad(r24);
        i17.setDefaultTrafficLightsForRoads();

        map.addRoad(r01);
        map.addRoad(r02);
        map.addRoad(r03);
        map.addRoad(r04);
        map.addRoad(r05);
        map.addRoad(r06);
        map.addRoad(r07);
        map.addRoad(r08);
        map.addRoad(r09);
        map.addRoad(r10);
        map.addRoad(r11);
        map.addRoad(r12);
        map.addRoad(r13);
        map.addRoad(r14);
        map.addRoad(r15);
        map.addRoad(r16);
        map.addRoad(r17);
        map.addRoad(r18);
        map.addRoad(r19);
        map.addRoad(r20);
        map.addRoad(r21);
        map.addRoad(r22);
        map.addRoad(r23);
        map.addRoad(r24);

        map.addIntersection(i01);
        map.addIntersection(i02);
        map.addIntersection(i03);
        map.addIntersection(i04);
        map.addIntersection(i05);
        map.addIntersection(i06);
        map.addIntersection(i07);
        map.addIntersection(i08);
        map.addIntersection(i09);
        map.addIntersection(i10);
        map.addIntersection(i11);
        map.addIntersection(i12);
        map.addIntersection(i13);
        map.addIntersection(i14);
        map.addIntersection(i15);
        map.addIntersection(i16);
        map.addIntersection(i17);

        return map;
    }

}
```

```java
package londonsw.view.simulation;

import londonsw.model.simulation.MapGrid;
import londonsw.model.simulation.components.Component;
import londonsw.model.simulation.components.IMapGrid;

/**
 * Created by felix on 25/02/2016.
 */
public abstract class MapGridDecorator implements IMapGrid {
    protected MapGrid decoratedMapGrid;

    public MapGridDecorator(MapGrid decoratedMapGrid) {
        this.decoratedMapGrid = decoratedMapGrid;
    }

    @Override
    public Component[][] getGrid() {
        return this.decoratedMapGrid.getGrid();
    }

    @Override
    public int getWidth() {
        return this.decoratedMapGrid.getWidth();
    }

    @Override
    public int getHeight() {
        return this.decoratedMapGrid.getHeight();
    }

    @Override
    public boolean addComponent(Component component) {
        return this.decoratedMapGrid.addComponent(component);
    }
}
```

```java
package londonsw.view.simulation;

import javafx.scene.Group;
import javafx.scene.Node;
import javafx.scene.layout.GridPane;
import javafx.scene.layout.Pane;
import javafx.scene.layout.StackPane;
import javafx.scene.paint.Color;
import javafx.scene.shape.Line;
import javafx.scene.shape.Polygon;
import londonsw.controller.MapMakerController;
import londonsw.model.simulation.MapGrid;
import londonsw.model.simulation.components.*;
import londonsw.view.mapcreation.ComponentType;

import java.util.ArrayList;

/**
 * This is the class that handles drawing of the entire map. It cycles through t
he Model grid and draws
 * each map component on the screen.
 */
public class MapGridGUIDecorator extends MapGridDecorator {

    private ResizeFactor resizeFactor;

    /**
     * Creates an instance of this decorator to represent a single Map
     * @param decoratedMapGrid the MapGrid (underlying Map data structure) to re
present graphically
     */
    public MapGridGUIDecorator(MapGrid decoratedMapGrid) {
        super(decoratedMapGrid);
    }

    /**
     * Gets the resize factor for this decorator
     * @return the resize factor for this decorator
     */
    public ResizeFactor getResizeFactor() {
        return resizeFactor;
    }

    /**
     * Sets the resize factor for this decorator
     * @param resizeFactor the resize factor to set for this decorator
     */
    public void setResizeFactor(ResizeFactor resizeFactor) {
        this.resizeFactor = resizeFactor;
    }

    /**
     * Draws the components for this Map
     * @return a GridPane representing the map, where every cell in the GridPane
 corresponds to a coordinate in the Map
     * @throws Exception
     */
    public GridPane drawComponents() throws Exception {
        GridPane rootGP = new GridPane();
        StackPane roadPane;

        int roadCounter = 0;

        ArrayList<RoadGUIDecorator> roadArray = new ArrayList<>();

        for (int y = 0; y < this.getHeight(); y++) {
            for (int x = 0; x < this.getWidth(); x++) {

                Component current = this.getGrid()[y][x];

                if (current instanceof Road) { // draws a Road

                    RoadGUIDecorator roadGUIDecorator = new RoadGUIDecorator((Ro
ad) current);

                    roadGUIDecorator.setResizeFactor(this.getResizeFactor());

                    roadPane = roadGUIDecorator.drawRoad();

                    roadPane.getChildren().get(1).setOnMouseClicked(event ->
                            {

                                if (event.getTarget() instanceof LaneArrow) {
                                    LaneArrow laneArrow = (LaneArrow) event.getT
arget();

                                    for (RoadGUIDecorator rd : roadArray
                                            ) {


                                        if (rd.decoratedRoad.getId() == roadGUID
ecorator.decoratedRoad.getId()) {

                                            Node nGroup = rd.getPane().getChildr
en().get(1);

                                            Group gRoad = (Group) nGroup;

                                            Group g = (Group) gRoad.getChildren(
).get(laneArrow.lane.getRoadIndex());

                                            Line lineArrow = (Line) g.getChildre
n().get(0);
                                            Polygon arrow = (Polygon) g.getChild
ren().get(1);

                                            lineArrow.setStroke(lineArrow.getStr
oke() == Color.RED ? Color.WHITE : Color.RED);
                                            arrow.setFill(arrow.getFill() == Col
or.RED ? Color.WHITE : Color.RED);

                                        }

                                    }

                                    System.out.println("Lane ID: " + laneArrow.lan
e.getId() + " Lane State: " + laneArrow.lane.getState());
                                    laneArrow.lane.setState(laneArrow.lane.getSt
ate() == 0 ? 1 : 0);

                                }
                            }
                    );

                    roadGUIDecorator.setCell(roadCounter);
                    roadGUIDecorator.setPane(roadPane);
                    roadGUIDecorator.setGridPaneCoordinates(new Coordinate(x, y)
);

                    roadArray.add(roadGUIDecorator);

                    roadCounter++;

                } else if (current instanceof Intersection) { // draws an Inters
ection
                    roadCounter = 0;

                    IntersectionDecorator intersectionDecorator = new Intersecti
onDecorator((Intersection) current);
                    intersectionDecorator.setResizeFactor(this.getResizeFactor()
);
                    roadPane = intersectionDecorator.drawIntersection();
                } else { // draws Grass
                    roadCounter = 0;

                    LayoutGUI grassGUI = new LayoutGUI();
                    grassGUI.setHeight(this.getHeight());
                    grassGUI.setWidth(this.getWidth());
                    grassGUI.setResizeFactor(this.getResizeFactor());
                    roadPane = grassGUI.drawGrass();
                }

                rootGP.add(roadPane, x, y);

            }
        }

        rootGP.setGridLinesVisible(true);

        return rootGP;
    }

    /**
     * Redraws the cell based on what is currently in the cell. Used by MapMaker
 mode.
     * @param x the x coordinate of the new component to be redrawn
     * @param y the y coordinate of the new component to be redrawn
     * @param gp the GridPane representing the Map
     * @return a StackPane representation of the newly redrawn grid cell
     */
    public StackPane redrawCell(int x, int y, GridPane gp) {
        Component component = this.getGrid()[y][x];
        StackPane sp = new StackPane();
        if(component instanceof Intersection) {
            IntersectionDecorator intersectionDecorator = new IntersectionDecora
tor((Intersection) component);
            intersectionDecorator.setResizeFactor(this.getResizeFactor());
            sp = intersectionDecorator.drawIntersection();
        }
        else if(component instanceof Road) {
            RoadGUIDecorator roadGUIDecorator = new RoadGUIDecorator((Road) comp
onent);
            roadGUIDecorator.setResizeFactor(this.getResizeFactor());
            sp = roadGUIDecorator.drawRoad();
        }
        else if(component == null) { // Grass
            LayoutGUI grassGUI = new LayoutGUI();
            grassGUI.setHeight(this.getHeight());
            grassGUI.setWidth(this.getWidth());
            grassGUI.setResizeFactor(this.getResizeFactor());
            sp = grassGUI.drawGrass();
        }
        gp.add(sp, x, y);
        return sp;
    }
}
```

```
package londonsw.view.simulation;

import londonsw.model.simulation.components.*;

import java.util.ArrayList;

/**
 * Created by felix on 25/02/2016.
 */
public abstract class RoadDecorator implements IRoad {

    protected Road decoratedRoad;

    public RoadDecorator(Road decoratedRoad) {
        this.decoratedRoad = decoratedRoad;
    }

    @Override
    public ArrayList<Lane> getLanes() {
        return this.decoratedRoad.getLanes();
    }

    @Override
    public void addLane(Lane lane) {
        this.decoratedRoad.addLane(lane);
    }

    @Override
    public Lane getLaneAtIndex(int index) {
        return this.decoratedRoad.getLaneAtIndex(index);
    }

    @Override
    public Coordinate getEndLocation() {
        return this.decoratedRoad.getEndLocation();
    }

    @Override
    public int getNumberLanes() {
        return decoratedRoad.getNumberLanes();
    }

    @Override
    public Intersection getIntersection() {
        return this.decoratedRoad.getIntersection();
    }

    @Override
    public void setIntersection(Intersection intersection) {
        this.decoratedRoad.setIntersection(intersection);
    }

    @Override
    public int getLength() {
        return this.decoratedRoad.getLength();
    }

    @Override
    public boolean runsVertically() {
        return this.decoratedRoad.runsVertically();
    }

    public boolean runsVertically(MapDirection mapDirection) {
        return this.decoratedRoad.runsVertically(mapDirection);
    }

}
```

```
package londonsw.view.simulation;

import javafx.scene.Group;
import javafx.scene.image.Image;
import javafx.scene.image.ImageView;
import javafx.scene.layout.Pane;
import javafx.scene.layout.StackPane;
import javafx.scene.shape.Line;
import londonsw.model.simulation.components.*;
import java.util.ArrayList;

/**
 * This class defines how roads are drawn and displayed in the view. Each Road i
nstance will
 * have exactly one of these decorators associated with it.
 */
public class RoadGUIDecorator extends RoadDecorator {

    private ResizeFactor resizeFactor;
    private Coordinate gridPaneCoordinates;
    private Pane paneRoad;
    private int Cell;

    /**
     * Creates a new instance of this decorator class for the given Road instanc
e
     * @param decoratedRoad the Road instance to associate this decorator with
     */
    public RoadGUIDecorator(Road decoratedRoad) {
        super(decoratedRoad);
    }

    /**
     * Gets the pane associated with this decorator
     * @return the pane for this decorator
     */
    public Pane getPane() {
        return paneRoad;
    }

    /**
     * Sets the pane for this decorator
     * @param paneRoad the pane to set for this decorator
     */
    public void setPane(Pane paneRoad) {
        this.paneRoad = paneRoad;
    }

    /**
     * Gets the cell for this road
     * @return the cell
     */
    public int getCell() {
        return Cell;
    }

    /**
     * Sets the cell for this road
     * @param cell the cell for this road
     */
    public void setCell(int cell) {
        Cell = cell;
    }

    /**
     * Gets the grid pane coordinate of this road
     * @return the coordinate for this road
     */
    public Coordinate getGridPaneCoordinates() {
        return gridPaneCoordinates;
    }

    /**
     * Sets the grid pane coordinate for this road
     * @param gridPaneCoordinates the coordinate for this road
     */
    public void setGridPaneCoordinates(Coordinate gridPaneCoordinates) {
        gridPaneCoordinates = gridPaneCoordinates;
    }

    /**
     * Gets the resize factor for this road
     * @return the resize factor for this road
     */
    public ResizeFactor getResizeFactor() {
        return resizeFactor;
    }

    /**
     * Sets the resize factor for this road
     * @param resizeFactor the resize factor to set for this road
     */
    public void setResizeFactor(ResizeFactor resizeFactor) {
        this.resizeFactor = resizeFactor;
    }

    /**
     * This method draws the road and returns the StackPane representation of th
is road. Each cell has a road background
     * image. Each cell also contains an arrow that displays the moving directio
n of that cell.
     * @return the StackPane representation of this road cell
     */
    public StackPane drawRoad() {

        String roadBackgroundPath = "RoadBackground.png";

        Image image = new Image(roadBackgroundPath);

        Image im = new Image(roadBackgroundPath, image.getHeight() * getResizeFa
ctor().getResizeX(), image.getWidth() * getResizeFactor().getResizeY(), false, f
alse);

        ImageView iv = new ImageView(im);

        StackPane stackPane = new StackPane();

        //draw amount of lines
        Group arrowLines = new Group();

        int numberLanes = this.getNumberLanes();

        ArrayList<Lane> lanes = this.getLanes();

        double division = im.getHeight();

        division = division / (numberLanes * 2);

        LaneArrow arrow;

        int j = 0;

        if (!this.runsVertically(lanes.get(0).getMovingDirection())) {
            for (int i = 0; i < numberLanes * 2; i++) {
                if (i % 2 == 0) {

                    Lane lane = lanes.get(j);

                    double lineStartX = 5;
                    double lineStartY = division * (i + 1);

                    double lineEndX = im.getWidth() - 10;
                    double lineEndY = division * (i + 1);

                    Line roadLine = new Line(lineStartX, lineStartY, lineEndX, l
ineEndY);

                    arrow = new LaneArrow(lane,roadLine,resizeFactor);

                    arrowLines.getChildren().addAll(arrow.getGroup());

                    j++;

                }
            }
        } else
            for (int i = 0; i < numberLanes * 2; i++) {

                if (i % 2 == 0) {

                    Lane lane = lanes.get(j);

                    double lineStartX = division * (i + 1);
                    double lineStartY = 5;
                    double lineEndX = division * (i + 1);
                    double lineEndY = im.getHeight() - 10;

                    Line roadLine = new Line(lineStartX, lineStartY, lineEndX, l
ineEndY);

                    arrow = new LaneArrow(lane,roadLine,resizeFactor);
                    arrowLines.getChildren().addAll(arrow.getGroup());

                    j++;

                }
            }
        stackPane.getChildren().add(iv);
        stackPane.getChildren().add(arrowLines);

        return stackPane;
    }
}
```

```
package londonsw.view.simulation;


import javafx.application.Platform;
import javafx.beans.value.ChangeListener;
import javafx.beans.value.ObservableValue;
import javafx.fxml.FXMLLoader;
import javafx.geometry.Insets;
import javafx.geometry.Pos;
import javafx.scene.Parent;
import javafx.scene.Scene;
import javafx.scene.control.*;
import javafx.scene.layout.*;
import javafx.scene.paint.Color;
import javafx.scene.text.Font;
import javafx.scene.text.TextAlignment;
import javafx.stage.Stage;
import londonsw.controller.StartUpController;
import londonsw.controller.TrafficLightController;
import londonsw.controller.VehicleController;
import londonsw.model.simulation.Map;
import londonsw.model.simulation.Ticker;
import londonsw.model.simulation.components.ResizeFactor;
import javafx.scene.text.FontWeight;
import londonsw.model.simulation.components.Lane;
import londonsw.model.simulation.components.Road;
import londonsw.model.simulation.components.vehicles.Ambulance;
import londonsw.model.simulation.components.vehicles.Car;
import londonsw.model.simulation.components.vehicles.Vehicle;
import rx.Subscriber;

import java.io.IOException;
import java.util.ArrayList;
import java.util.Optional;
import java.util.Random;


@SuppressWarnings("Duplicates")
public class SimulationScreen {

    private Map map;
    private int initCar = 0;
    private int flag = 0;
    private int systemState = 0;
    private int maxCarSize;
    Subscriber<Long> timeLabelSubscriber;
    Label carNumberSituation;
    Label timeStanding;

    public SimulationScreen(Map map) {
        this.map = map;
    }

    public void drawScreen(Stage primaryStage) throws Exception {
        // the entire screen building and logic will go here
        // http://docs.oracle.com/javafx/2/layout/builtin_layouts.htm

        BorderPane borderPane = new BorderPane();
        borderPane.setStyle("-fx-background-color:papayawhip");

        //Title
        Label logo = new Label("LondonSW Traffic Simulation");
        logo.setFont(Font.font("System Bold Italic", FontWeight.EXTRA_BOLD, 20));
        logo.setAlignment(Pos.CENTER);
        logo.setTextAlignment(TextAlignment.CENTER);
        logo.setPadding(new Insets(10, 10, 10, 10));
        borderPane.setTop(logo);

        //Map
        StackPane mapStackPane = new StackPane();
        Map map = this.map;
        MapGridGUIDecorator mapGridGUIDecorator = new MapGridGUIDecorator(map.ge
tGrid());
        ResizeFactor rf = ResizeFactor.getSuggestedResizeFactor(map.getWidth(),
map.getHeight());
        mapGridGUIDecorator.setResizeFactor(rf);
        GridPane mapGridPane = mapGridGUIDecorator.drawComponents();
        mapStackPane.setPadding(new Insets(0, 0, 5, 5));

        mapStackPane.getChildren().add(mapGridPane);
        borderPane.setCenter(mapStackPane);

        //Start&Reset
        VBox simulationControl = new VBox();

        simulationControl.setPadding(new Insets(0,10,10,10));
        simulationControl.setSpacing(8);
        simulationControl.setAlignment(Pos.TOP_CENTER);

        carNumberSituation = new Label();
        carNumberSituation.setFont(Font.font("System Bold Italic",FontWeight.BOLD,13)
);
        carNumberSituation.setText("Number of cars: " + String.valueOf(initCar));
        simulationControl.getChildren().add(carNumberSituation);

        Label tickerSituation = new Label();
        tickerSituation.setFont(Font.font("System Bold Italic",FontWeight.BOLD,13));
        tickerSituation.setText("Ticker Interval: " + Ticker.getTickInterval() + " ms"
);
        simulationControl.getChildren().add(tickerSituation);

        Label trafficLightLabel = new Label();
        trafficLightLabel.setFont(Font.font("System Bold Italic",FontWeight.BOLD,13))
;
        trafficLightLabel.setText("Traffic Light Duration: " + TrafficLightController.ge
tInstance().getDurationLength()/1000 + " ticks");
        simulationControl.getChildren().add(trafficLightLabel);

        Label timeLabel = new Label();
        timeLabel.setFont(Font.font("System Bold Italic",FontWeight.BOLD,13));
        timeLabel.setText("Times ticked: 0");
        simulationControl.getChildren().add(timeLabel);

        timeStanding = new Label();
        timeStanding.setFont(Font.font("System Bold Italic",FontWeight.BOLD,13));
        timeStanding.setText("Vehicle Time Spent Standing: 0.0%");
        simulationControl.getChildren().add(timeStanding);
        Button startSimulation = new Button("Start");
        startSimulation.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 13))
;
        startSimulation.setStyle("-fx-base:Gold");

        Button resetSimulation = new Button("Reset");
        resetSimulation.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 13))
;
        resetSimulation.setStyle("-fx-base:Gold");

        Button backButton = new Button("Back");
        backButton.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 16));
        backButton.setStyle("-fx-base:Gold");

        startSimulation.setPadding(new Insets(10, 10, 10, 10));
        startSimulation.setPrefSize(90, 30);
        simulationControl.getChildren().add(startSimulation);

        resetSimulation.setPadding(new Insets(10, 10, 10, 10));
        resetSimulation.setPrefSize(90, 30);
        simulationControl.getChildren().add(resetSimulation);
        resetSimulation.setDisable(true);

        Button ambulanceAddDelete = new Button("Add Ambulance");
        ambulanceAddDelete.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 1
3));
        ambulanceAddDelete.setStyle("-fx-base:Gold");
        ambulanceAddDelete.setPrefSize(200, 30);
        ambulanceAddDelete.setDisable(true);
        simulationControl.getChildren().add(ambulanceAddDelete);

        Button trafficLightInterval = new Button("Set Traffic Light Duration");
        trafficLightInterval.setFont(Font.font("System Bold Italic", FontWeight.BOLD,
 13));
        trafficLightInterval.setStyle("-fx-base:Gold");
        trafficLightInterval.setPrefSize(200, 30);
        simulationControl.getChildren().add(trafficLightInterval);

        Button enableDisableLights = new Button("Disable Traffic Lights");
        enableDisableLights.setFont(Font.font("System Bold Italic", FontWeight.BOLD,
13));
        enableDisableLights.setStyle("-fx-base:Gold");
        enableDisableLights.setPrefSize(200, 30);
        simulationControl.getChildren().add(enableDisableLights);

        Label instructions = new Label("Click on the lane arrows to\nenable and disable lanes.");
        instructions.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 13));
        instructions.setPadding(new Insets(5,0,0,0));
        simulationControl.getChildren().add(instructions);

        //carSlider
        VBox sliderControl = new VBox();
        sliderControl.setPadding(new Insets(10, 10, 5, 10));
        Pane carLabel = new Pane();
        Label carNumber = new Label("Car Number");
        carNumber.setFont(Font.font("System Bold Italic", FontWeight.BOLD, 13));
        carLabel.getChildren().add(carNumber);
        sliderControl.getChildren().add(carLabel);
```

```java
        Pane carSlider = new Pane();
        carSlider.setPadding(new Insets(10,10,10,10));
        Slider slider = new Slider();
        int maxSize = determineMaxCarSize(map);
        slider.setPrefWidth(250);
        slider.setMax(maxSize);
        slider.setMin(1);
        slider.setDisable(true);
        slider.setShowTickMarks(true);
        if(maxSize <= 20) {
            slider.setMajorTickUnit(5);
            slider.setMinorTickCount(2);
            slider.setBlockIncrement(1);
        }
        else if(maxSize <= 50) {
            slider.setMajorTickUnit(10);
            slider.setMinorTickCount(4);
            slider.setBlockIncrement(1);
        }
        else if(maxSize <= 100) {
            slider.setMajorTickUnit(20);
            slider.setMinorTickCount(10);
            slider.setBlockIncrement(1);
        }
        else {
            slider.setMajorTickUnit(20);
            slider.setMinorTickCount(2);
            slider.setBlockIncrement(1);
        }

        carSlider.getChildren().add(slider);
        sliderControl.getChildren().add(carSlider);
        simulationControl.getChildren().add(sliderControl);
        simulationControl.getChildren().add(backButton);
        borderPane.setRight(simulationControl);
        borderPane.setPickOnBounds(false);


        /**
         * Back to ChooseSimulationMode Screen
         */
        backButton.setOnMouseClicked(click->{
            ArrayList<Vehicle> vehicles = VehicleController.getVehicleList();
            int size = vehicles.size();
            for(int i = 0; i < size; i++) {
                VehicleController.removeVehicle(0);
            }
            Ticker.end();
            StartUpController.getInstance().goToChooseModeScreen(primaryStage);
            primaryStage.centerOnScreen();
            primaryStage.setResizable(false);

        });

        /**
         * Allows the user to change the traffic light interval
         */
        trafficLightInterval.setOnMouseClicked(click -> {
            Dialog<Long> dialog = new Dialog<Long>();
            dialog.setTitle("Choose Traffic Light Duration");
            dialog.setHeaderText("Choose a duration (in time ticks) for\nthe traffic lights in the system.
");
            dialog.setGraphic(null);
            dialog.getDialogPane().getButtonTypes().addAll(ButtonType.OK, Button
Type.CANCEL);
            GridPane grid = new GridPane();
            grid.setHgap(10);
            grid.setVgap(10);
            grid.setPadding(new Insets(20, 80, 10, 10));
            grid.add(new Label("Duration:"), 0, 0);
            Spinner<Double> spinner = new Spinner<Double>(1, 20, TrafficLightCon
troller.getInstance().getDurationLength()/1000, 1);
            grid.add(spinner, 1, 0);
            dialog.getDialogPane().setContent(grid);
            Platform.runLater(() -> spinner.requestFocus());

            dialog.setResultConverter(dialogButton -> {
                if(dialogButton == ButtonType.OK) {
                    double value =  spinner.getValue();
                    value *= 1000;
                    return (long) value;
                }
                return null;
            });

            Optional<Long> result = dialog.showAndWait();
            result.ifPresent((aLong -> {
                TrafficLightController.getInstance().setDurationLength(aLong);
                TrafficLightController.getInstance().setTrafficLightDuration(aLo
ng);
                trafficLightLabel.setText("Traffic Light Duration: " + TrafficLightContr
oller.getInstance().getDurationLength()/1000 + " ticks");
            }));

        });

        /**
         * Functionality for enabling and disabling the traffic lights
         */
        enableDisableLights.setOnMouseClicked(click -> {
            if(TrafficLightController.getInstance().areLightsEnabled()) {
                // disable the lights!
                TrafficLightController.getInstance().disableLights(true);
                enableDisableLights.setText("Enable Traffic Lights");
                trafficLightLabel.setText("Traffic Light Duration: DISABLED");
            }
            else {
                // enable the lights!
                TrafficLightController.getInstance().disableLights(false);
                enableDisableLights.setText("Disable Traffic Lights");
                trafficLightLabel.setText("Traffic Light Duration: " + TrafficLightContr
oller.getInstance().getDurationLength()/1000 + " ticks");
            }
        });

        /**
         * Using a slider control the number of cars in the system
         */
        slider.valueProperty().addListener(new ChangeListener<Number>() {
            @Override
            public void changed(ObservableValue<? extends Number> observable, Nu
mber oldValue, Number newValue) {
                initCar = oldValue.intValue();
                int newCar = newValue.intValue() - oldValue.intValue();

                //increase carNumber
                if (newCar >= 0) {
                    for (int i = 0; i < newCar; i++) {
                        generateCar(map, mapGridGUIDecorator, mapStackPane);
                    }
                }
                //decrease carNumber
                else {
                    int toDelete = newCar * -1;
                    for(int i = 0; i < toDelete; i++) {
                        ArrayList<Vehicle> vehicles = VehicleController.getVehic
leList();
                        if(vehicles.size() == 0) return;
                        Random rand = new Random();
                        int min = 0;
                        int max = vehicles.size();
                        int randomIndex = rand.nextInt((max - min)) + min;
                        while(vehicles.get(randomIndex) instanceof Ambulance) {
                            randomIndex = rand.nextInt((max - min)) + min;
                        }
                        VehicleController.removeVehicle(randomIndex);
                    }
                }
                ArrayList<Vehicle> vehicles = VehicleController.getVehicleList()
;
                carNumberSituation.setText("Number of cars: " + vehicles.size());
            }
        });

        /**
         * "Add/Delete Ambulance" Button click control
         * the first click adds an ambulance in the system, the next click will
delete the ambulance, next add...
         */
        ambulanceAddDelete.setOnMouseClicked(click -> {
            if (flag == 0) {
                generateAmbulance(map, mapGridGUIDecorator, mapStackPane);
                ambulanceAddDelete.setText("Delete Ambulance");
                flag = 1;
            } else {
                flag = 0;
                ArrayList<Vehicle> vehicles = VehicleController.getVehicleList()
;
                for (int i = 0; i < vehicles.size(); i++) {
                    if (vehicles.get(i).getVehiclePriority() == 5) {
                        VehicleController.removeVehicle(i);
                    }
                }
                ambulanceAddDelete.setText("Add Ambulance");
            }
            carNumberSituation.setText("Number of cars: " + VehicleController.getVeh
icleList().size());
        });

        Scene scene = new Scene(borderPane);

        primaryStage.setScene(scene);
        primaryStage.centerOnScreen();

        /**
         * Starts the simulation
         */
        startSimulation.setOnMouseClicked(click->{
            systemState = 1;
            ambulanceAddDelete.setDisable(false);
            slider.setDisable(false);
            initCar = (int) slider.getValue();
            carNumberSituation.setText("Number of cars: " + initCar);

            for (int i = 0; i < initCar; i++) {
                generateCar(map, mapGridGUIDecorator, mapStackPane);
            }

            startSimulation.setDisable(true);
            resetSimulation.setDisable(false);

            Platform.runLater(() -> slider.requestFocus());
            startTimeLabelTicker(timeLabel);
        });


        /**
         * To stop simulation
         */
        resetSimulation.setOnMouseClicked(click -> {
            systemState = 0;
            slider.setDisable(true);
            startSimulation.setDisable(false);
            resetSimulation.setDisable(true);
            ambulanceAddDelete.setText("Add Ambulance");
            ambulanceAddDelete.setDisable(true);

            //reset lanes to enabled //TODO

            ArrayList<Vehicle> vehicles = VehicleController.getVehicleList();
            int size = vehicles.size();
            for(int i = 0; i < size; i++) {
                VehicleController.removeVehicle(0);
            }
            carNumberSituation.setText("Number of cars: " + VehicleController.getVeh
icleList().size());
            Platform.runLater(() -> startSimulation.requestFocus());
            endTimeLabelTicker();
            timeLabel.setText("Times ticked: 0");
            timeStanding.setText("Vehicle Time Spent Standing: 0.0%");
        });
    }

    /**
     * Creates a subscriber that listens to the ticker to update the "times tick
```

```
ed" label
     * @param timeLabel the label to update on every tick
     */
    private void startTimeLabelTicker(Label timeLabel) {
        timeLabelSubscriber = new Subscriber<Long>() {
            int timesTicked = 0;
            @Override
            public void onCompleted() {

            }

            @Override
            public void onError(Throwable throwable) {

            }

            @Override
            public void onNext(Long aLong) {
                timeLabel.setText("Times ticked: " + timesTicked);
                timesTicked++;
                carNumberSituation.setText("Number of cars: " + VehicleController.ge
tVehicleList().size());
                timeStanding.setText("Vehicle Time Spent Standing: " + getPercentageStan
ding() + "%");
            }
        };
        Ticker.subscribe(timeLabelSubscriber);
    }

    /**
     * Stops the time ticker label from listening to the ticker
     */
    private void endTimeLabelTicker() {
        timeLabelSubscriber.unsubscribe();
    }

    private double getPercentageStanding() {
        int timeSpentStanding = VehicleController.getTotalTimeSpentStanding();
        int totalTimesTicked = VehicleController.getTotalTimesTicked();
        if(totalTimesTicked == 0) {
            return 0.0;
        }
        double ans = (double) timeSpentStanding / totalTimesTicked * 100;
        return Math.round(ans * 100.0) / 100.0;
    }

    /**
     * Determines the maximum number of cars that should go in the system
     * @param map the map the simulation is happening on
     * @return an upper bound on the number of cars that should be in the system
     */
    public int determineMaxCarSize(Map map){
        int numberSlots = 0;
        ArrayList<Road> roads = map.getRoads();
        for(Road i:roads){
            ArrayList<Lane> lanes = i.getLanes();
            for(Lane l:lanes){
                numberSlots += l.getLength();
            }
        }
        maxCarSize = (int)(0.6 * numberSlots);
        return maxCarSize;
    }

    /**
     * Car generator
     * @param map
     * @param mapGridGUIDecorator
     * @param sp
     * @return
     */
    public Car generateCar(Map map, MapGridGUIDecorator mapGridGUIDecorator, Sta
ckPane sp) {
        Lane L1 = map.getRandomLane();
        if (L1 != null) {
            for (int a = 0; a < map.getRoads().size(); a++) {
                for (int b = 0; b < map.getRoads().get(a).getNumberLanes(); b++)
 {
                    Lane L2 = map.getRoads().get(a).getLanes().get(b);
                    for (int i = 0; i < L1.getLength(); i++) {
                        if (L1.isCellEmpty(i)) {
                            Car C1 = new Car(i, L1);
                            //C1.setVehicleBehavior(VehicleBehavior.AGGRESSIVE);
                            VehicleGUIDecorator vehicleGUIDecorator = new Vehicl
eGUIDecorator(C1);
                            vehicleGUIDecorator.setResizeFactor(mapGridGUIDecora
tor.getResizeFactor());
                            vehicleGUIDecorator.drawCar();
                            Pane carPane = new Pane();

                            carPane.setPickOnBounds(false); //allows me to click
 intersections

                            carPane.getChildren().add(vehicleGUIDecorator.getRec
tangle());
                            sp.getChildren().add(carPane);
                            vehicleGUIDecorator.setPane(carPane);
                            vehicleGUIDecorator.setVehicleState(1);
                            return C1;

                        }
                    }
                }
            }
        }
        return null;
    }

    /**
     * Ambulance generator
     * @param map
     * @param mapGridGUIDecorator
     * @param sp
     * @return
     */
    public Ambulance generateAmbulance(Map map, MapGridGUIDecorator mapGridGUIDe
corator, StackPane sp) {
        Lane AmbLane = map.getRandomLane();
        if (AmbLane != null && (!AmbLane.isFull())) {
            for (int x = 0; x < map.getRoads().size(); x++) {
                for (int y = 0; y < map.getRoads().get(x).getNumberLanes(); y++)
 {
                    AmbLane = map.getRandomLane();
                    for (int z = 0; z < AmbLane.getLength(); z++) {
                        if (AmbLane.isCellEmpty(z)) {
                            Ambulance A = new Ambulance(z, AmbLane);
                            VehicleGUIDecorator ambulanceGUIDecorator = new Vehi
cleGUIDecorator(A);
                            ambulanceGUIDecorator.setResizeFactor(mapGridGUIDeco
rator.getResizeFactor());
                            ambulanceGUIDecorator.setColor(Color.RED);
                            ambulanceGUIDecorator.drawCar();
                            Pane alPane = new Pane();
                            alPane.setPickOnBounds(false);
                            alPane.getChildren().add(ambulanceGUIDecorator.getRe
ctangle());
                            ambulanceGUIDecorator.setPane(alPane);
                            sp.getChildren().add(alPane);
                            ambulanceGUIDecorator.setVehicleState(1);
                            return A;

                        }
                    }

                }

            }
        }
        return null;
    }
}
```

```
package londonsw.view.simulation;

import javafx.scene.paint.Color;
import javafx.scene.shape.Circle;
import londonsw.controller.TrafficLightController;
import londonsw.model.simulation.components.LightColour;
import londonsw.model.simulation.components.TrafficLight;

import java.io.Serializable;

/**
 * Traffic Light GUI Logic is implemented here. One instance of this class is as
sociated with exactly one instance
 * of a TrafficLight.
 */
public class TrafficLightDecorator implements Serializable {

    private static final long serialVersionUID = 8123065437897754089L;
    private TrafficLight thisLight;
    private Circle circle;

    /**
     * Creates a new instance of the TrafficLightDecorator for the GUI.
     * @param thisLight the instance of a TrafficLight that this decorator is fo
r
     */
    public TrafficLightDecorator(TrafficLight thisLight) {
        this.thisLight = thisLight;
        circle = new Circle();
        TrafficLightController.getInstance().addTrafficLightAndDecoratorPair(thi
sLight, this);
    }

    /**
     * This gets called by the controller to set the color of the circle of the
traffic light gui
     * @param colour
     */
    public void setGUIColour(LightColour colour) {
        switch (colour) {
            case RED:
                circle.setFill(Color.RED);
                break;

            case GREEN:
                circle.setFill(Color.GREEN);
                break;
        }
    }

    /**
     * Returns the circle associated with this decorator
     * @return circle for this traffic light
     */
    public Circle getCircle() {
        return circle;
    }

    /**
```

```
     * Hides the circle representing the traffic light from the GUI. This is cal
led when enabling and disabling
     * traffic lights.
     * @param hide true will hide the circle, false will display the circle
     */
    public void hideCircle(boolean hide) {
        if(hide)
            circle.setVisible(false);
        else
            circle.setVisible(true);
    }

    /**
     * Draws the circle for the GUI
     * @param x the x-position in its pane
     * @param y the y-position in its pane
     * @param r the radius of the circle
     * @return a new Circle with those properties
     */
    public Circle drawLight(double x, double y, double r){
        circle.setCenterX(x);
        circle.setCenterY(y);
        circle.setRadius(r);
        circle.setFill(thisLight.getState() == LightColour.RED? Color.RED : Colo
r.GREEN);
        return circle;
    }

}
```

```java
package londonsw.view.simulation;

import londonsw.model.simulation.components.Coordinate;
import londonsw.model.simulation.components.Lane;
import londonsw.model.simulation.components.TrafficLight;
import londonsw.model.simulation.components.VehicleBehavior;
import londonsw.model.simulation.components.vehicles.IVehicle;
import londonsw.model.simulation.components.vehicles.Vehicle;

import java.util.ArrayList;

/**
 * Created by felix on 26/02/2016.
 */
public abstract class VehicleDecorator implements IVehicle {

    protected Vehicle decoratedVehicle;

    public VehicleDecorator(Vehicle decoratedVehicle) {
        this.decoratedVehicle = decoratedVehicle;
    }

    @Override
    public Lane getPreviousLane() {
        return decoratedVehicle.getPreviousLane();
    }

    @Override
    public void setPreviousLane(Lane previousLane) {
        decoratedVehicle.setPreviousLane(previousLane);
    }

    public void setPreviousCoordinate(Coordinate coord) {
        decoratedVehicle.setPreviousCoordinate(coord);
    }

    @Override
    public void setCurrentCoordinate(Coordinate currentCoordinate) {
        decoratedVehicle.setCurrentCoordinate(currentCoordinate);
    }

    @Override
    public int getVehicleLength() {
        return decoratedVehicle.getVehicleLength();
    }

    @Override
    public double getVehicleSpeed() {
        return decoratedVehicle.getVehicleSpeed();
    }

    @Override
    public int getVehiclePriority() {
        return decoratedVehicle.getVehiclePriority();
    }

    @Override
    public Lane getCurrentLane() {
        return decoratedVehicle.getCurrentLane();
    }

    @Override
    public int getCurrentCell() {
        return decoratedVehicle.getCurrentCell();
    }

    @Override
    public int getVehicleState() {
        return decoratedVehicle.getVehicleState();
    }

    @Override
    public VehicleBehavior getVehicleBehavior() {
        return decoratedVehicle.getVehicleBehavior();
    }

    @Override
    public Coordinate getCurrentCoordinate() {
        return decoratedVehicle.getCurrentCoordinate();
    }

    public Coordinate getPreviousCoordinate() {
        return decoratedVehicle.getPreviousCoordinate();
    }


    public Coordinate getStoredCurrentCoordinate() {
        return decoratedVehicle.getStoredCurrentCoordinate();
    }

    @Override
    public void setVehicleLength(int vehicleLength) {
        decoratedVehicle.setVehicleLength(vehicleLength);
    }

    @Override
    public void setVehicleSpeed(double vehicleSpeed) {
        decoratedVehicle.setVehicleSpeed(vehicleSpeed);
    }

    @Override
    public void setVehiclePriority(int vehiclePriority) {
        decoratedVehicle.setVehiclePriority(vehiclePriority);
    }

    @Override
    public void setCurrentLane(Lane currentLane) throws Exception {
        decoratedVehicle.setCurrentLane(currentLane);
    }

    @Override
    public void setCurrentCell(int curCell, Lane currentLane) throws Exception {
        decoratedVehicle.setCurrentCell(curCell,currentLane);
    }

    @Override
    public void setVehicleState(int vehicleState) {
        decoratedVehicle.setVehicleState(vehicleState);
```

```java
    }

    @Override
    public void setVehicleBehavior(VehicleBehavior vehicleBehavior) {
        decoratedVehicle.setVehicleBehavior(vehicleBehavior);
    }

    @Override
    public int moveVehicle(int step) throws Exception {
        return decoratedVehicle.moveVehicle(step);
    }

    @Override
    public void readTrafficLight() throws Exception {
        decoratedVehicle.readTrafficLight();
    }

    @Override
    public ArrayList<Lane> getLaneOptions() throws Exception {
        return decoratedVehicle.getLaneOptions();
    }

    @Override
    public Lane chooseLane () throws Exception{
        return decoratedVehicle.chooseLane();
    }

    @Override
    public int vehicleTurn(Lane l) throws Exception {
        return decoratedVehicle.vehicleTurn(l);
    }

    @Override
    public int getVehiclePriorityToTurn(){
        return decoratedVehicle.getVehiclePriorityToTurn();
    }

    @Override
    public void setVehiclePriorityToTurn(int vehiclePriorityToTurn){
         decoratedVehicle.setVehiclePriorityToTurn( vehiclePriorityToTurn);
    }
    @Override
    public TrafficLight getVehicleTrafficLight(){
        return decoratedVehicle.getVehicleTrafficLight();
    }
    @Override
    public void setVehicleTrafficLight(TrafficLight vehicleTrafficLight){
        decoratedVehicle.setVehicleTrafficLight(vehicleTrafficLight);
    }


}
```

```
package londonsw.view.simulation;

import javafx.animation.*;
import javafx.beans.property.DoubleProperty;
import javafx.scene.Group;
import javafx.scene.layout.GridPane;
import javafx.scene.layout.Pane;
import javafx.scene.layout.StackPane;
import javafx.scene.paint.Color;
import javafx.scene.shape.Rectangle;
import javafx.util.Duration;
import londonsw.controller.VehicleController;
import londonsw.model.simulation.Ticker;
import londonsw.model.simulation.components.Coordinate;
import londonsw.model.simulation.components.MapDirection;
import londonsw.model.simulation.components.ResizeFactor;
import londonsw.model.simulation.components.vehicles.Vehicle;

/**
 * This class is to draw vehicles and display them in the GUI. Each vehicle will
 have exactly one VehicleGUIDecorator
 * associated with it.
 */
public class VehicleGUIDecorator extends VehicleDecorator {

    private double imageDimension;
    private Rectangle rectangle;
    private ResizeFactor resizeFactor;
    private Color color;
    private double verticalStartFudgeFactor;
    private double horizontalStartFudgeFactor;
    private Pane pane;

    /**
     * Creates a new instance of this decorator class
     * @param decoratedVehicle the Vehicle to be associated with
     */
    public VehicleGUIDecorator(Vehicle decoratedVehicle) {
        super(decoratedVehicle);
        VehicleController.addVehicleAndDecoratorPair(decoratedVehicle,this);
        imageDimension = 100.0;
        verticalStartFudgeFactor = 0;
        horizontalStartFudgeFactor = 0;
    }

    /**
     * Sets the resize factor for this vehicle to display properly
     * @param resizeFactor the resize factor for the simulation
     */
    public void setResizeFactor(ResizeFactor resizeFactor) {
        this.resizeFactor = resizeFactor;
    }

    /**
     * Gets the resize factor for the simulation
     * @return
     */
    public ResizeFactor getResizeFactor() {
        return resizeFactor;
    }

    /**
     * Gets the rectangle of the vehicle
     * @return the rectangle representing the vehicle
     */
    public Rectangle getRectangle() {
        return rectangle;
    }

    /**
     * Sets the rectangle of the vehicle
     * @param rectangle the rectangle to represent the vehicle
     */
    public void setRectangle(Rectangle rectangle) {
        this.rectangle = rectangle;
    }

    /**
     * Gets the pane of the vehicle
     * @return the pane the vehicle resides in
     */
    public Pane getPane() {
        return pane;
    }

    /**
     * Sets the pane of the vehicle
     * @param pane the pane to set
     */
    public void setPane(Pane pane) {
        this.pane = pane;
    }

    /**
     * Gets the color of the vehicle
     * @return the Color of this vehicle
     */
    public Color getColor() {
        return color;
    }

    /**
     * Sets the color of the vehicle
     * @param color the color of the vehicle
     */
    public void setColor(Color color) {
        this.color = color;
    }

    /**
     * Gets the vehicle associated with this decorator class
     * @return the vehicle this decorator class is for
     */
    public Vehicle getVehicle() {
        return decoratedVehicle;
    }
    /**
     * Draws the vehicle to display in the simulation. Each vehicle would have t
his method called on it.
     */
    public void drawCar() {
        double cellDimension = imageDimension;

        int numberLanes = this.getCurrentLane().getRoad().getNumberLanes();
        double carDimensionX = cellDimension;
        double carDimensionY = cellDimension;
        double angle = 0.0;

        // determine the start location of the vehicle in the map
        Coordinate coordinate = this.getCurrentCoordinate();
        double[] start = coordinateToPixels(coordinate,this.getCurrentLane().get
MovingDirection());
        double startPointX = start[0];
        double startPointY = start[1];

        // determine the size of the vehicle based on the size of the map
        if(this.getCurrentLane().getRoad().runsVertically())
        {
            carDimensionX = cellDimension/numberLanes − 50*resizeFactor.getResiz
eX();
            carDimensionY −= 15;
            if(resizeFactor.getResizeX() <= 0.25) {
                carDimensionX = cellDimension/numberLanes − 80*resizeFactor.getR
esizeX();
            }
            verticalStartFudgeFactor = −carDimensionX*resizeFactor.getResizeX();
        }
        else {
            carDimensionY = cellDimension/numberLanes − 50*resizeFactor.getResiz
eX();
            carDimensionX −= 15;
            if(resizeFactor.getResizeX() <= 0.25) {
                carDimensionY = cellDimension/numberLanes − 80*resizeFactor.getR
esizeX();
            }
            horizontalStartFudgeFactor = −carDimensionY*resizeFactor.getResizeX(
);
        }

        Rectangle r = new Rectangle(
                startPointX,
                startPointY,
                carDimensionX * this.getResizeFactor().getResizeX(),
                carDimensionY * this.getResizeFactor().getResizeY());

        /**
         * Simulating Ambulance using fill Transitions
         *
         */
        FillTransition ft = new FillTransition();
        ft.setShape(r);
        ft.setDuration(Duration.millis(500));
        if(this.getVehiclePriority()==5) {
            ft.setFromValue(this.getColor());
            ft.setToValue(Color.BLUE);
            ft.setCycleCount(Timeline.INDEFINITE);
            ft.setAutoReverse(true);
            ft.setInterpolator(Interpolator.LINEAR);
            ft.play();
        }

        else
            r.setFill(Color.YELLOW);

        r.setRotate(angle);

        this.setRectangle(r);
    }

    /**
     * Moves the vehicle in the GUI based on the state of the vehicle. A vehicle
 is either stopped, moving through
     * an intersection, moving straight down a road, or left the simulation.
     * @param step how much to move the vehicle by
     * @param state the state of the vehicle
     */
    public void moveVehicleGUI(int step, int state) {

        final Timeline timeline = new Timeline();
        //timeline.setAutoReverse(true);

        /* move the car according to moving direction, below */
        if(state == 0) { // car must stop because red light, or something in the
 way
            timeline.stop();
        }
        else if(state == 2)  //car is at intersection
        {
            TranslateTransition tt = new TranslateTransition(Duration.millis(Tic
ker.getTickInterval()), this.getRectangle());
            MapDirection fromDirection = this.getPreviousLane().getMovingDirecti
on();
            MapDirection toDirection = this.getCurrentLane().getMovingDirection(
);

            Coordinate coordinate = this.getPreviousCoordinate();

            double fromXPixels = rectangle.xProperty().doubleValue();
            double fromYPixels = rectangle.yProperty().doubleValue();

            // determine new position of vehicle
            Coordinate fromTranslation = directionToTranslation(fromDirection);
            Coordinate toTranslation = directionToTranslation(toDirection);
            Coordinate overallTranslation = Coordinate.add(fromTranslation,toTra
nslation);
            Coordinate newPosition = Coordinate.add(overallTranslation,coordinat
e);

            // work out rotation
            int rotation = getRotationFromDirectionChange(fromDirection,toDirect
ion);

            // determine pixel locations for the actual animation
            double[] toPixels = coordinateToPixels(newPosition,toDirection);
            double toXPixels = toPixels[0];
            double toYPixels = toPixels[1];

            // set the movement translation
            tt.setToX(toXPixels − fromXPixels);
            tt.setToY(toYPixels − fromYPixels);

            // move and rotate the car
            RotateTransition rt = new RotateTransition();
            rt.setNode(tt.getNode());
            rt.setByAngle(rotation);
            rt.setDuration(Duration.millis(Ticker.getTickInterval()));
            rt.play();
            tt.play();
            this.setVehicleState(1);

        }
        else if(state == 3) {
            //Car deleted state
            this.getPane().getChildren().remove(this.getRectangle());
        }
        else // car driving straight down road
        {
            TranslateTransition tt = new TranslateTransition(Duration.millis(Tic
ker.getTickInterval()), this.getRectangle());

            Coordinate coordinate = this.getPreviousCoordinate();
            MapDirection toDirection = this.getCurrentLane().getMovingDirection(
);

            double fromXPixels = rectangle.xProperty().doubleValue();
            double fromYPixels = rectangle.yProperty().doubleValue();

            // determine new location for car to move to
            Coordinate toTranslation = directionToTranslation(toDirection);
            Coordinate newPosition = Coordinate.add(toTranslation,coordinate);

            // determine pixel locations for the actual animation
            double[] toPixels = coordinateToPixels(newPosition,toDirection);
            double toXPixels = toPixels[0];
            double toYPixels = toPixels[1];

            // set the translation animation based on moving direction
            if(toDirection == MapDirection.NORTH || toDirection == MapDirection.
SOUTH)
                tt.setToY(toYPixels − fromYPixels);
            else if(toDirection == MapDirection.EAST || toDirection == MapDirect
ion.WEST)
                tt.setToX(toXPixels − fromXPixels);

            // play the animation
            tt.play();
        }
    }

    /**
     * Determines the pixel location for a vehicle if it occupies Coordinate c a
nd traveling in the MapDirection direction.
     * Each grid cell location is determined by the image dimension, resized by
```

```
the resize factor, and the lane the
     * vehicle should occupy.
     * @param c the Coordinate where the vehicle will be
     * @param direction the MapDirection that coordinate is moving, to determine
 the proper lane for the vehicle
     * @return an array of length 2, where index 0 is the x−coordinate and index
 1 is the y−coordinate. This is so you can get
     * both x− and y−locations at once, without calling the function twice.
     */
    private double[] coordinateToPixels(Coordinate c, MapDirection direction) {
        double[] pixels = new double[2];
        int x = c.getX();
        int y = c.getY();
        if(direction == MapDirection.NORTH) {
            pixels[0] = x * imageDimension * resizeFactor.getResizeX() + (.1 * i
mageDimension * resizeFactor.getResizeX() + horizontalStartFudgeFactor);
            pixels[1] = y * imageDimension * resizeFactor.getResizeX() − horizon
talStartFudgeFactor;
        }
        else if(direction == MapDirection.EAST) {
            pixels[0] = x * imageDimension * resizeFactor.getResizeX() + (.1 * i
mageDimension * resizeFactor.getResizeX() − verticalStartFudgeFactor);
            pixels[1] = y * imageDimension * resizeFactor.getResizeX() + (.1 * i
mageDimension * resizeFactor.getResizeX() + verticalStartFudgeFactor);
        }
        else if(direction == MapDirection.WEST) {
            pixels[0] = x * imageDimension * resizeFactor.getResizeX() − vertica
lStartFudgeFactor;
            pixels[1] = y * imageDimension * resizeFactor.getResizeX() + (.6 * i
mageDimension * resizeFactor.getResizeX() + verticalStartFudgeFactor);
        }
        else if(direction == MapDirection.SOUTH) {
            pixels[0] = x * imageDimension * resizeFactor.getResizeX() + (.6 * i
mageDimension * resizeFactor.getResizeX()) + horizontalStartFudgeFactor;
            pixels[1] = y * imageDimension * resizeFactor.getResizeX() + (.1 * i
mageDimension * resizeFactor.getResizeX()) − horizontalStartFudgeFactor;
        }

        return pixels;
    }

    /**
     * Determines the vehicle rotation required based on where it is coming from
 and where it is going to. Possible
     * rotations are −90 for turning left, 90 for turning right, or 0 for drivin
g straight.
     * @param fromDirection the direction the vehicle is coming from
     * @param toDirection the direction the vehicle is moving to
     * @return integer representing how much to rotate the vehicle by (90, −90,
or 0)
     */
    private int getRotationFromDirectionChange(MapDirection fromDirection, MapDi
rection toDirection) {
        if(
                (fromDirection == MapDirection.SOUTH && toDirection == MapDirect
ion.EAST) ||
                (fromDirection == MapDirection.NORTH && toDirection == MapDirect
ion.WEST) ||
                (fromDirection == MapDirection.EAST && toDirection == MapDirecti
on.NORTH) ||
                (fromDirection == MapDirection.WEST && toDirection == MapDirecti
on.SOUTH)) {
            return -90;
        }
        else if(
                (fromDirection == MapDirection.EAST && toDirection == MapDirecti
on.SOUTH) ||
                (fromDirection == MapDirection.SOUTH && toDirection == MapDirect
ion.WEST) ||
                (fromDirection == MapDirection.WEST && toDirection == MapDirecti
on.NORTH) ||
                (fromDirection == MapDirection.NORTH && toDirection == MapDirect
ion.EAST)) {
            return 90;
        }
        else {
            return 0;
        }
    }

    /**
     * Translates a moving direction into a Coordinate translation. For instance
, moving north means moving 0 squares in the x
     * direction and -1 square in the y direction. This is used for determining
overall movement of vehicles.
     * @param fromDirection the direction the vehicle is moving from or to
     * @return a Coordinate representing the 2-d translation required for that m
ap direction
     */
    private Coordinate directionToTranslation(MapDirection fromDirection) {
        switch (fromDirection) {
            case NORTH:
                return new Coordinate(0,-1);
            case SOUTH:
                return new Coordinate(0,1);
            case EAST:
                return new Coordinate(1,0);
            case WEST:
                return new Coordinate(-1,0);
        }

        return null;
    }
}
```