King's College London

Traffic Simulator

Group Project

Team Diversity

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1 Introduction

1.1 Background

Over the past few decades, the world's population has been continuously increasing which is becoming a big issues in many countries. This has resulted in overwhelming traffic in the most cities around the world. City planners are therefore looking for ways to solve problems caused by traffic congestion. There are many theories and methods to handle this issues. For example, in Bangkok, priority lanes are used at peak hour to relive traffic congestion. Above all, any theories and methods which are applied for solving this problem will need to be used together with a good traffic management policy.

In this report, we will explain how our traffic simulator works and how the simulator implements two different traffic management policies. These policies can be compared and therefore give implication which policy would be more likely to solve problems in the real world. This traffic simulator are supposed to be an abstract models of the real world, so if a policy works well on the simulator it probably will work well in the real world. This is the reason why traffic simulators are made.

1.2 Descriptions

The traffic simulator is an abstract model of actual real world traffic. Roads can have multiple lanes which can go in either direction. The traffic is left lane oriented, as in the UK. The simulator has cars and buses, which differ in size and speed. Drivers can be either cautious, reckless or normal. There are two different traffic management policies fixed time policy and congestion control policy. These policies are compared by average time each vehicle is in the system. Our opinion is that two types of vehicles and three types of driver behaviour gives enough diversity for comparing the different policies, more types of vehicles wouldn't give more accurate results.

The simulator will be programmed in Java programming language. The simulator will have a graphical user interface (GUI). The GUI is created with the help of JavaFX software platform. The rational for using a GUI: 1. Better visualisation and understanding of code during development, i.e. actually seeing what is happening when programming. 2. When the final product is ready users can see the road system and the cars and therefore get a better understanding of how the road system is and how the policies work. Opposed to just get the result log and results of which policy is superior and have no visual understanding of what happened.

1.3 Objectives

Our initial objectives for this project where as follows.

- To develop a traffic simulator program which has the following structure: two types of vehicles, three types of drivers, functional road system with many roads and lanes, junctions, intersections and traffic lights.

- To compare two different traffic management policies: Fixed Time Policy and Congestion Control Policy.
- To examine how the system reacts in an emergency period by injecting an ambulance to the simulation.

1.4 Scope

- Each road can have multiple lanes, which can be in the same or opposite direction.
- British traffic is left-lane oriented.
- The system has only two types of vehicle (cars and buses).
- There are three types of driver behaviour which is cautious, reckless, and normal.

1.5 Methodology

I. Analysing: requirement

II. Planing and Organising: schedule and assigned task

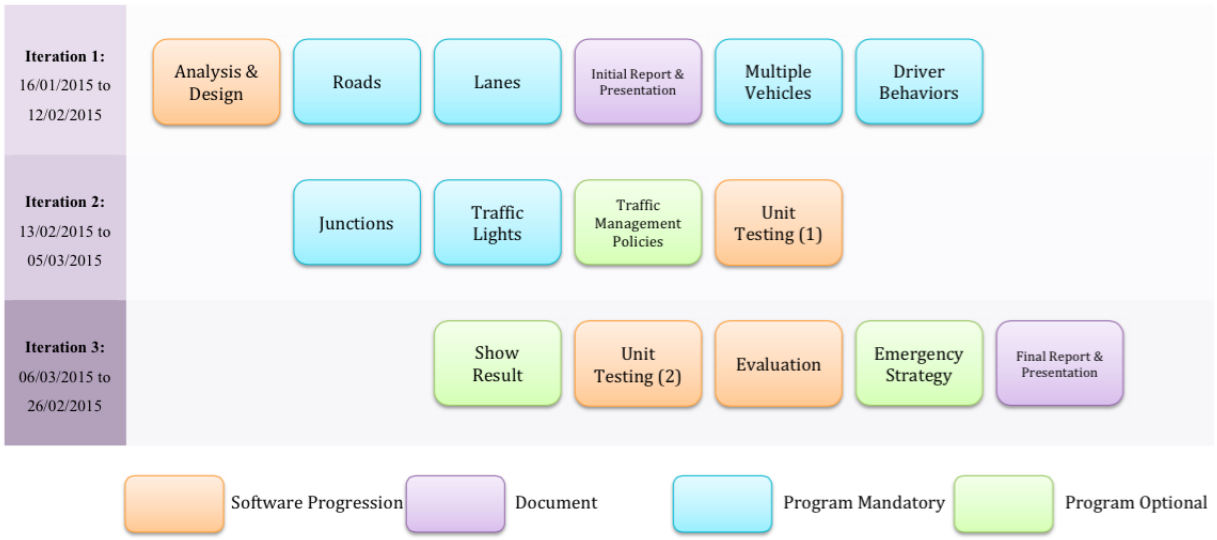
III. Developing:
   - Software: used Java
   - Source code: stored at GitHub

IV. Evaluating:
   - Program
   - Peer Assessment

V. Reporting:
   - Document: written by LaTeX
   - Presentation

1.6 Schedule

The development phase (10 weeks) was divided into three iteration. In the first iteration (week 1 to week 4), our team focused on requirement and design. After we had committed to a plan, we started to develop the simulator. In the second iteration (week 5 to week 7) we continued to complete tasks and functions that we had defined as mandatory as well as well as starting to work on implementing the traffic management policies and we started to make unit tests. In the last iteration (week 8 to week 10) much work was done on fine tuning the implementation on the traffic lights and the policies to get correct results. Evaluation of the whole project was also done. However, the emergency strategy was left out due to lack of time. The detail of traffic simulator progress is illustrated in the figure below.



1.7 Obstacles

Culture and Language :

Our member come four different countries (Hungary, Iceland, Thailand and Uganda) in three different continents. English isn't the native language for any member. Those cultural and language differences have been an obstacle we have had to face.

Communication is one of the most important aspect for team work. So when we have had a difficult time explaining our thoughts and meaning we have tried to use other means of communication. For instance, pictures and picture drawing have been used a lot to help other members understand some point or a concept.

Skill and Background :

The teams members have different skills and background in programming. Some members have worked or are currently working as software developers and some have little experience. However, this project is also about communication, reporting, presentation and more.

We quickly discovered the strengths and weaknesses of each team member. This has always been taken into account when allocating of work. So we have tried to use our strengths to our advantage. We have tried to help each other with tasks, for instance, a member that has much knowledge on some tool helps another member to understand how to use that particular tool.

Time :

We had only 10 weeks for developing the traffic simulator. That is not a long time if taken into account that team members didn't know each other beforehand.

However, we had a task schedule for each person in deep detail. That helped us to follow up our task and complete the project on time.

2 Review

2.1 Related work

In today's world a lot of effort is made to make transportation as good as possible. For most countries and cities the road systems is a vital part of it's transportation system. With the ever growing population and increasing purchasing power of the public, good traffic control has never been as urgent. Changes to road systems are hard to make and drivers wouldn't be pleased if many experiments were made on live traffic. That's why traffic simulators play a big role in increasing the quality of the road system. Any change can be simulated and the result of the change can be analysed. There are many challenges that traffic simulation creators face. Trying to predict the behaviour of drivers and the synergistic effects of different factors can have on a driver behaviour is perhaps the most challenging, the goal is to make it as realistic as possible.

Many traffic simulators exist as well as many papers and books on that subject. In this module we were given two papers on traffic simulation for inspiration for this project and an insight into this field. Sewall, Wilkie, Merrell and Lin [5]presented a novel method for the synthesis and animation of realistic traffic flows on large-scale road networks. Their technique is based on a continuum model of traffic flow they extended to correctly handle lane changes and merges, as well as traffic behaviours due to changes in speed limit. They demonstrated how their method can be applied to the animation of many vehicles in a large-scale traffic network at interactive rates and showed that their method can simulate believable traffic flows on publicly available, real-world road data. They furthermore demonstrated the scalability of this technique on many-core systems.

Namekawa, F. Ueda, Hioki, Y. Ueda and Satoh [1] spent several years developing a general purpose road-traffic simulation system to analyse road traffic jams. The concept of their system was using the running line model as opposed to fixed road-network information database, which is not effective in their opinion. Their simulator uses the a cell automaton model.

2.2 Theory

1. **Driver's Behaviour:** In the paper, it is going to categorise the driver's behaviour into three types (normal, cautious, and reckless). In the program, driver's behaviour is defined by the average speed of the vehicle, as followed.
   - Normal: It is generally accepted that this behaviour has a normal average speed of vehicle, respect the transportation rule.
   - Cautious: Normally, this behaviour drives slower than normal average. This behaviour is very careful, avoid a danger.
   - Reckless: It is obviously that reckless behaviour drives faster than average speed. It may be overtake the front vehicle or change lanes immediately.

2. **Passenger Car Unit:** There are a number of types of vehicle in there traffic which is various in different locations. Traffic modelling utilises a common unit, know as Passenger Car Unit, to standardise general traffic. SCPtransport [**?**] states that "A Passenger Car Unit (PCU) is a method used in Transport Modelling to allow for the different vehicle types within a traffic flow group to be assessed in a consistent manner." TFL (Transport for London) [**?**] is defined PCU value in a figure below.

Vehicle Type	PCU Value
Pedal Cycle	0.2
Motor Cycle	0.4
Passenger Car	1.0
Light Goods Vehicle (LGV)	1.0
Medium Goods Vehicle (MGV)	1.5
Buses & Coaches	2.0
Heavy Goods Vehicle (HGV)	2.3
Articulated Buses	3.2*

** Recent research conducted for TfL has suggested this to be an appropriate PCU value for articulated buses[36].*

3. **Road Intersection:** According to Andy Chow Lectures 11-12, [**?**] points out that a road intersection or junction is a location of multiple road intersect. This can be divide into five types of intersection, as shown below

   - Uncontrolled: no signs or road markings
   - Roundabouts: traffic circulates around a central island and leaves at a chosen exit
   - Priority: signs and road markings indicate way
   - Signal Control: priority as indicated by signal
   - Grade Separation: conflicting traffic stream, having different level

4. **Traffic Signal Lights:** Traffic Signal or Traffic Lights is a set of coloured lights to control the flow of traffic on the junction. It may use in different meaning or types in another country. In the United Kingdom, the meaning and types is followed

   - RED: stop and wait behind the stop line on the carriageway
   - RED and AMBER: stop and do not pass through or start until GREEN shows

- GREEN: may go on if the way is clear, take special care if you intend to turn left or light and give way to pedestrians who are crossing
- AMBER: stop at the stop line, you may go on if the AMBER appears after you have crossed the stop line or are so close to it that to pull up might cause an accident.
- GREEN ARROW: same as GREEN but may go on in the arrow sign.

5. **Traffic Management Policy:** In this paper, it will focus on two different traffic management policies— Fixed Time and Congestion Control. Those policies will be compared which one is better by the average time. Each vehicle will have a timer that starts when it enters the system and gets written to a log when the vehicle exits the system. Therefore, the average time that a vehicle is in the system is calculated and the the policy that generates lower average time is considered better.

   - Fixed Time: This is about the peak period and off-peak period during a day which has been applied to a system. The concept of this policy is very simple. In a peak time period, the green light on the desire direction, especially in the business centre area, will be longer than another directions. And off-peak time period, it will be set the traffic light time equally. which is no one the get more priority.
   - Congestion Control: This policy is is the policy that automatically changes the duration of the traffic light due to a congestion of the traffic in a simultaneous time. In this programme, the congestion is set by the PCU (Passenger Car Unit) in the road which those vehicle waited. The program will calculate the PCU in every road at this intersection. Suppose that the program has four path—A, B, C, D. If path A has the highest PCU , path A will get a first priority. After the cycle time, the program will calculate the PCU in this junction again.

3 Requirement and Design

3.1 Requirement

3.2 Design

3.3 Maps

3.3.1 Drivers & Vehicles

3.3.2 Traffic Policies

3.3.3 Running the Simulation

4 Implementation

4.1 Maps

Flexible model
Map, Roads, Lanes, Junctions
Class Diagram
Usage examples

4.2 Drivers & Vehicles

The abstract class Vehicle has all the logic that is needed for the vehicles. The Bus and Car classes inhered from the Vehicle class and these classes pass different values to the Vehicle class. Making cars and buses have different speed, acceleration, deceleration and size. The vehicle class keeps record on what lane it is currently on and also what lane the vehicle will enter at next intersection. The next lane decision is made as soon as the vehicle enters a lane. That makes it easier to keep correct distance between vehicles at intersections.

The abstract class Driver has all the logic that is needed for the vehicles. The CautiousDriver, NormalDriver and RecklessDriver classes inhered from the Driver class and these classes pass different values to the Driver class. Making the different drivers have different acceleration and deceleration.

When initiating a vehicle, car or a bus, that vehicle needs a driver, either cautious, normal or reckless.

4.3 Traffic Policies

Traffic Lights
Fixed time & congestion policies

4.4 Running the Simulation

Simulation class and subclasses
ISteppable interface
timing
Generating cars
Results

4.5 Testing

Because the navigation of the user interface is very simple and the system doesn't depend other systems our opinion was that unit testing was the most useful method of testing we could use. For unit testing we used the JUnit library. JUnit is a very easy to use library and has been important in the development of test-driven development (TTD). We set out to use TTD for the most of the project but that was too time consuming so

only parts of the project were developed with TTD. The parts that were developed with TDD were the creation of roads and lanes.

4.6 Graphical User Interface

In our application, JavaFX is selected as a graphic platform to be used. This platform allows developers to create an application on various platform such as desktop, mobile, or web. Furthermore, this platform introduce the use of cascading style sheets (CSS) to decorate the interface. This way, coders won't have to worry about decorating the interface themselves in their codes and let CSS designer to handle this instead. Although in our application the use of this benefit haven't been implemented along with the java code but we think that this is a very helpful technique worth mentioned from JavaFX. Our application consists of 2 stages, which are both a top-level container of JavaFX, one is the main stage that will show a simulation and another one is the one used to show a simulation's result. The first stage is separated into 2 parts by using Border pane. This pane works like BorderLayout in Javaswing but in JavaFX this layout is implemented into a pane rather than being one of the layout to be set into an empty pane. The followings are put into left and center region of this border pane respectively:

4.6.1 Main Stage

[need fix on sectioning]The first stage is separated into 2 parts by using Border pane. This pane works like BorderLayout in Javaswing but in JavaFX this layout is implemented into a pane rather than being one of the layout to be set into an empty pane. The followings are put into left and center region of this border pane respectively.

4.6.2 Canvas

Canvas is a node that is a blank image. This node can be painted on using GraphicsContext class object. Our canvas has a width of 800 pixels and height of 600 pixels so we don't have to worry about how our application will run in different screen resolution since this dimension is probably comply with all present screen resolutions. To draw a simulation, we can call a GraphicsContext object from canvas itself using `getGraphicsContext2D()` and by doing so, we can manipulate the canvas with various methods from GraphicsContext like `fillPolygon(double[] X, double[] Y)` which will draw a polygon with specified fill colour from a set of coordinate X and Y. To draw roads, we can call an above method and get a set of parameters from a simulation class which contains a list of roads. Each road can provide its own coordinate at each corner so we use this as elements to be added into a set of X and Y coordinate. Because this is a "fill" type method which will also paint an enclosure of a polygon we can provide only 3 points to the method which these are `leftStartPoint`,`leftEndPoint`, and `rightEndPoint`. The method automatically close the gap between a start point and last point with a straight line and fill a polygon afterwards. For vehicles, we have already provided a picture for each type of vehicle in a JPEG format and draw these pictures based on what type of vehicle we

are dealing with from a list of vehicle provided from simulation class. There is a useful method in Vehicle class called `getDisplacementVector()`, using this method along with the one in Point class from utils package called `angleVectorDegree()` we obtain an angle in which a vehicle is running compare to a horizontal line measuring In counter-clockwise manner. After we obtained a value of angle, a method called `drawRotatedImage()` will do a job to draw a vehicle picture onto a canvas. This method, again, call another method `rotate()` which receive 4 parameters consist of GraphicsContext object, angle value, x-position, and y-position where these x and y form a coordinate in which will be an anchor point of the rotation. After that, we create a rotate class object by using above parameters. This rotate class object will perform a calculation in order to make a GraphicsContext rotate before we actually draw something using it. After we have rotated the GraphicsContext, we can normally draw a picture onto a canvas. Note that all of these happened after the start button is pressed, which the button will send a signal to start a simulation.

4.6.3 Settings panel

In this panel, we take an advantage from JavaFX features called HBox and VBox, which will place objects horizontally and vertically next to previous one by specified insets. The idea is to put many Hboxes into one VBox but since radio buttons still require us to put them in vertically, so we have put one VBox into Hbox to be able to put radio buttons in their correct position. Figure x given below will give an overall image of how we put each component together within this pane (HBox indicated by red border, VBox indicated by black border and object are indicated by blue green border).

4.6.4 Result stage

This stage will only appear after the simulation has ended and user press the result button that locates aside of the start button. A simulation will pass various information onto a new stage which will behave as child of the main stage. This means that some behaviour like minimizing and closing will be done to this stage too, if it's happened with its parent. This stage use GridPane which allow us to create a table-liked contents to show to users. A constructor required enough data from a simulation to create a report to user of a current simulation that just has ended.

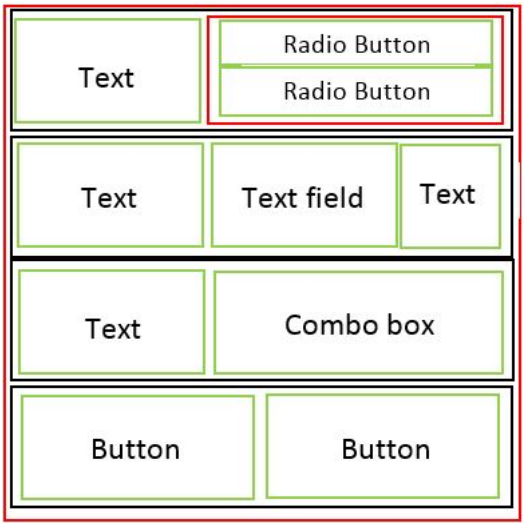

Text
Radio Button
Radio Button
Text
Text field
Text
Text
Combo box
Button
Button

Figure x

5 Team Work

In this chapter we'll describe how we worked together during this project, including the tools and processes we used to facilitate group work. We'll will not reflect on what went wrong and what worked well, that is the focus of chapter 6 - Evaluation.

5.1 Methodology

A slightly adjusted Agile methodology was used for this project. What is meant be that is we did not follow Agile to the bone but we took bits and pieces from Agile that we knew from previous studies and work experience. The bits and pieces we chose to use from Agile are things that we believed would work for us in this project, i.e. iterations, user stories, roles and we used test driven development to some extend.

5.1.1 Roles

Balázs Kiss: Lead programmer
Eddy Mukasa: Architect
Yukolthep Visessmit: Graphical designer
Pongsakorn N. Riyamongkol: Project Manager
Snorri Hannesson: Tester and Coordinator

Each member of the group had a responsibility to oversee one aspect of the project but was not expected to do all the work defined in his role. I.e. each member should/could do some programming but the lead programmer should oversee the code and make sure nothing is missing and everything is done properly. The same goes for the other roles.

5.2 Physical meetings

Every Thursday at 10 o'clock we had a physical meetings where all team members were expected to attend. We kept log of our meetings so those who were unable to attend the meeting could get up to date by reading the log and for those who did attend the meeting to refresh their memory of what was discussed in the meeting. In these meetings we discussed the progress we made from last meeting and the problems we were faced with. At the end of each meeting we allocated work to each member witch is supposed to be done during the week until next meeting. Occasionally extra meetings have been scheduled where a certain aspect of the project been focused on. Not all members are expected to attend these meetings but only the members who are focusing on this certain aspect of the project.

5.3 GitHub

Github was used for version control. Our branching strategy was that every time a member wanted to implement a new feature to the system or write something to the report, a new branch was created for that feature. When that branch was created it

would be up to date with the master. When work were done on that branch a pull request would be made to the master. The leader of that aspect of the project would then decide to merge or to create a new branch with suggestions of improvements or alterations. Those improvements could then be merged with the original branch which could then be merged with master.

5.4 Facebook

Facebook was used as a communication channel. The first thing this team did was to create a facebook group for the team. Most people these days use facebook everyday so this is very convenient communication channel. In this group we would have various discussions about the our progresses or problems. The facebook chat was also used for individual members to discuss matters that were not directly associated to the group as a whole but only the members in the chat.

5.5 Trello

Trello is a versatile tool which was used for project management. The rationale for using Trello is that it's very flexible so you can modify the interface to your will. In this project not all tasks were code related which is not a problem when using Trello.

6 Evaluation

In this chapter, we SWOT analysis to evaluate our team and our work. This is very helpful methodology for analysing and evaluating. Moreover, we will then focus on the currents status of the system and future possibilities for the system. Therefore, this evaluation chapter is separated into four parts - our team, our program, current status, and future possibilities.

6.1 Our Team

Strengths :

- Team spirit and mutual respect: The team have had a good team spirit from day one. That have resulted in good collaboration between team members. This is very positive and is the reason we were able achieve the project goals. In other words, this is our strength and is making us successful in our task.
- Good work ethics: This means that each member has been efficient in his work and has shown initiative. Moreover, positive attitude and enthusiasm has been prevailing in this project. Thus, this is the reason why good work ethics has been an advantage point for our team.

Weaknesses :

- Skill: Because the members of the team have different skills the scenario can happen that a lot of work falls on few hands. Although other team members are eager and willing to help with some task they can't because they don't have the skill set.

- Punctuation and truancy: During the course of this project we have only had one scheduled meeting per week. It is important that most if not all members attend this meeting, to get up to speed, and be punctual, to get the most of the meeting. Both poor attendance and members being late have been a problem.

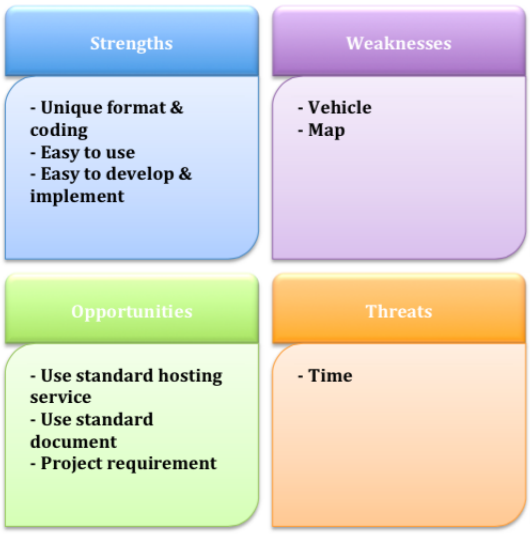
Opportunities :

- Scheduler and Planner: Having only 10 weeks to finish the project forced us to do as good schedule as possible. Therefore, this is an opportunity for our team to be successful.
- Course Objective: Our members are very appreciative for the opportunity to work as a team. This is very useful for us when working with other people in the future. So, this is an advantage that we can take with us.

Threats :

- Language: communication is very important for an effective team, but our member's native language isn't English. This can result in an misunderstanding. However, have been able to communicate together by using other methods especially pictures, and examples. This means that we have overcome this threat and has improved a lot in communication over the course of this project.

6.2 Our Program



Strengths :

- Unique format and coding: This Traffic Simulator Program has developed in Java programming language and for GUI is used JavaFX platform. This means that all code in our program is unique and same format. This leads to be easy to run and comply a program; moreover, it is very useful for coding a program when we combine and migrate function in this program together. So our program is written in a same format, structure and language.
- Easy to use: Our user interface is easy to use and understandable and friendly to everyone.
- Easy to develop and implement: As the unique format and coding mentioned before, it is the fundamental principle for developing and implementing the program. Our program is very easy to develop and implement due to the unique format and coding. If the next developer would like to develop/change/implement, this system require only JAVA programming skill. In addition, our program is written in JAVA, so any platform which support JAVA is able to implement and run the program as well. Hence, this is a reason why our program is good at development and implement.
- Quality: The quality of the code is good. We have tried to follow the simple principles of 'don't repeat yourself' (DRY) and 'keep it simple stupid' (KISS)

Weaknesses :

- Vehicle: The simulator has only two types of vehicles, which is obviously not realistic for the real world wherein many other types of vehicles exist. However, we believe that this isn't a big factor in testing which of our policies

is superior. Moreover, how the system is designed it would be very easy to add new types of vehicles if one wanted to do that with future development.

- Map: We do not use maps that are an exact replica of some place in the real world. This makes the simulator less useful.
- Testing: We set out to use test-driven development (TDD) for most of the project. Although some aspects of the project were developed with that method most of the program wasn't. This is because of TDD was too time consuming. Moreover, the overall testing of the software isn't at the place we aimed at.
- Change lanes: Vehicles cannot change lanes.
- No left-hand rule: We haven't implemented any prioritisation at when vehicles meet. That means that only one lane can have a green light at each time on an intersection or else result in many car crashes.

Opportunities :

- Github: We were forced to use GitHub. And we are really grateful for that because now we see that Git and Github are very useful and powerful tools.
- LaTex: We were forced to use LaTeX. And we are really grateful for that because now we see that LaTeX much better than other word processing programs.
- Project requirement: the project requirement would like us to develop a simulation engine for testing traffic management policies. This is about vehicle, driver behaviour, traffic light management, and traffic management policy. If we have not got these requirement, as mentioned before, our simulator program will not be good. Hence, this is an opportunity for us to show our ability in the programming, teamwork and related useful skills.

Threats :

- Time: The limitation of time is an obvious threat that we have faced in our program. This is because we have 10 weeks for developing a simulator. It sounds that we have enough time to do a program, but we may not complete all of the project requirement within 10 weeks. The project requires a number of function especially in the vehicle types. Although this seem to be an obstacle for use, this help us to create a critically plan for complete a task. This help us to look for solutions or methods to run this project on time (not perfect, as we expect). Above all, if we have got time more than 10 weeks, we strongly can finish perfect simulator program than before. So, this is our threat that we cannot control and difficult to get rid off.

6.3 Current Status

According to our plan and objectives, we have done all mandatory tasks as well as traffic management policy and show result, that were defined as optional tasks. We didn't have time to make and implement the emergency strategy. The emergency strategy was defined as optional for our traffic simulator program. We tried to follow our plan as much as possible, but some aspects of the program took more time than we expected. This was because of unexpected complications that we hadn't thought of. However, we believe this simulator can give a good implication of which policy is superior.

6.4 Future Possibilities

The simulator could be improved with further development in theses aspects:

- Emergency Strategy
- Implement a lane changing method.
- Implement a prioritisation for vehicles at intersections (left-had rule)
- Types of vehicle: assign more vehicle (i.e. trucks, motorcycle, bicycle, and van etc.)
- Real map and traffic route.
- Adding more or more thought through traffic management polices.

7 Result

After a simulation has ended, we obtain a set of data regarding to that simulation in the result window. Some of these data, especially average time, can be used to analyze the effect of each traffic policy or to compare them between two policies. In traffic management study, we will use the following in order to analyze a simulation or even to the real world.

7.1 Shortest time

[may need to change to numerical list later]This data tells users how many smallest seconds for a vehicle to leave the system. A really small value of this type of result does not tell much about the effect of each policy as there might be some vehicles that enter a system with good timing so that they arrive at the junction when a traffic signal for that road turns green. The more that this value getting close to the average time the more it tells us that a policy is working well. The reason behind this logical conclusion is that most of the vehicles that went into the system left the system nearly as fast as the fastest vehicle so when we calculate for the average, the value will be as near as the shortest time if most of the input is very close to the shortest time. The table below shows an example of this situation.

Vehicle#	Time(seconds)
1	18
2	17
3	23
4	21
5	30
6	19
7	17
8	20
9	22
10	18

Table x

We can see that the average time is $\frac{\sum Time}{10} = 20.5$ seconds, which is only 3 seconds more than the shortest time.

7.2 Longest time

In contrast to the shortest time, this data tells users the opposite which is the longest time a vehicle take to leave the system. A really large value in this case can be divided into 2 different situation. First is that, it warns users that a selected traffic management policy may has something wrong since there is at least a single vehicle that has to stay in the system for a long time, compared to the average or not. Second, on the other

hand, might happen just because there is a vehicle that appear to stuck twice at the junction where others have already left. Another thing that this value tells us, similarly to the shortest time, is that as this value getting near the average time it can be a sign that our traffic policy that we used to run a simulation is not very effective. Consider again a table like the one above but this time most vehicles will have an average time nearly as long as the longest time.

Vehicle#	Time(seconds)
1	32
2	30
3	27
4	31
5	30
6	28
7	31
8	29
9	29
10	28

Table x

This time, the average time is $\frac{\sum Time}{10} = 29.5$ seconds. So most of them took nearly as long as the longest time (32 seconds) in this case.

7.3 Average time

This is one of the most important factor to be used in analyzing how effective each policy can be. It gives users a broad view of the system as a whole, not specific to a single vehicle. One of the advantage we can take from obtaining this valuable data is that we can make a better decision when there are more than one system to be managed (which always be). Assume the situation that there are three systems in our interest and either two of them can lead to the last one, we can compare their average time simulated with various policies and choose the best result. This result can help drivers to make a decision in which system should they take to reach their destination system as fast as possible.

8 Peer Assessment

Robert T. [4] states that "The term peer assessment refers to the process of having the learners critically reflect upon, and perhaps suggest grades for, the learning of their peers." In the other words, peer assessment is a process which student are able to assess their friends based on the criteria. This causes student to provide some feedbacks and evaluate their friends, which may help learning together (University of Reading, [2]). Therefore, TeamDiversity is going to use the peer assessment method for grading our member. This will be going to focus on the methodology which is used for assessment following by the criteria. It will be then shown the result and summary of each member in TeamDiversity.

8.1 How do we evaluate our member?

I. Distribute the assessment form and assessment criteria to our member.

II. In each member, he/she must score himself/herself as well as other group member. For example, if our team has 4 people, it will grade 1 for yourself and 3 for our friends.

III. When you have completed a score (your friends and yourself), you need to mark total add up all scores and calculate the average score for yourself.

IV. We use only the average score to evaluate our friends and present in this report.

8.2 What is the criteria that we have used?

University of Sydney [3] has published the assessment criteria and form on the website. TeamDiversity has adapted both documents in the appropriate way for supporting our task. This criteria is going to evaluate ten aspects of member behaviour. In each aspect, we have scored in the range from 0—10. Thus, the total marks of each member will vary from 0—100 inclusive. There will be then illustrated the detail in each aspect of peer assessment criteria, as followed

A. Quantity of Work:
0 - not taking part in it, having no prospect of progress/value
1—2 - doing a particular, not too much but enough
3—4 - sometimes above standard, generally needs improvement
5—6 - satisfactory, doing more than requirement
7—8 - always working hard and consistent
9—10 - outstanding, always over productivity standards

B. Quality of Work:
0 - not giving sufficient attention, making frequent mistakes
1—2 - giving attention, making some mistakes

3—4 - doing well, basically correct
5—6 - satisfactory, accurate in some aspect
7—8 - almost accurate in all involving fields
9—10 - outstanding, perfect work

C. Communication Skills:

0 - having bad manners, not showing respect for other people, not listen
1—2 - friendly and easy to talk to once know by others
3—4 - warm and friendly, sociable
5—6 - showing good manners, kindly, listens and understands
7—8 - courteous and respectful, best wish
9—10 - Inspiring to others, excellent at listening and understanding

D. Initiative:

0 - acts without plan/purpose
1—2 - need encouragement to do task
3—4 - putting in minimal effort to complete task
5—6 - desire to achieve task/goal
7—8 - strongly desire to achieve task/goal
9—10 - beyond duty, high motivation

E. Efficiency:

0 - always delayed
1—2 - occasionally finished on time
3—4 - usually finished on time, having minor errors
5—6 - always finished on time
7—8 - absolutely completed, consistent in troubleshooting and solving major problems
9—10 - invariably completed ahead of schedule, showing creativity, making major contributions

F. Personal Relations:

0 - very disruptive influence
1—2 - some friction
3—4 - no problem, commonly
5—6 - satisfactory, tuneful, harmonious
7—8 - positive factor
9—10 - respect by others

G. Group Meeting Attendance:

0 - never attended to meeting, not interest
1—2 - sometime attended
3—4 - usually attended, hard to get touch with

5—6 - attend, normally late
7—8 - count on to attend
9—10 - never ever missed a meeting, on time

H. Attitude and Enthusiasm:
0 - low disposition, having no prospect of value, unconcerned
1—2 - feeling/showing few excitement, blasé
3—4 - half hearted
5—6 - positive outward behaviour/bearing
7—8 - positive attitude and spirited
9—10 - excitement and eager, inspiring to others, positive thinking and influence

I. Effort:
0 - expects others to carry the load
1—2 - leave some effort
3—4 - displays enough endeavour
5—6 - firm and stable contributions
7—8 - energetic
9—10 - self starter, normally beyond duty

J. Dependability:
0 - unreliable
1—2 - unsteady, but slightly dependability
3—4 - inconsistent, occasionally be
5—6 - suitable, need some improvement
7—8 - very trustworthy, responsibility
9—10 - always responsible, steady influence

8.3 Result and summary of peer assessment?

Name	A	B	C	D	E	F	G	H	I	J	Total	Allocate 100
Balazs Kiss	8.8	8.8	7.6	8.4	7.6	7.6	7.8	8.0	8.6	8.4	81.60	20.29
Eddy Mukasa	7.6	7.8	7.8	8.0	7.8	8.0	7.4	8.2	7.8	8.2	78.60	19.54
Pongsakorn Riyamongkol	7.4	7.4	8.4	8.4	7.8	7.8	7.8	8.6	8.2	8.2	80.00	19.89
Snnorri Hannesson	8.4	8.4	8.8	8.8	8.2	7.8	7.8	8.8	8.4	8.6	83.40	20.74
Yukolthep Visessmit	8.0	7.8	7.8	7.8	7.2	7.6	8.2	8.6	7.4	8.2	78.60	19.54
										Total	**402.20**	**100.00**

References

[1] M Namekawa, F Ueda, Y Hioki, Y Ueda, and A Satoh. General purpose road traffic simulation system with a cell automaton model. In *International Congress on Modelling and Simulation (MODSIM05), Melbourne, Australia*, 2005.

[2] University of Reading. Peer assessment, 2015.

[3] The University of Sydney. Completing self and peer assessment, 2010.

[4] Tim S Roberts. *Self, peer and group assessment in e-learning.* IGI Global, 2006.

[5] Jason Sewall, David Wilkie, Paul Merrell, and Ming C Lin. Continuum traffic simulation. In *Computer Graphics Forum*, volume 29, pages 439–448. Wiley Online Library, 2010.

A Gitlog

Author	Date	Message
Balázs Kiss	2015-01-25	Initial architecture
Balázs Kiss	2015-01-26	Ignore build directory
snh11	2015-01-26	Meeting log created, first three meetings documented
Snorrihann	2015-01-26	A template for the initial report
Snorrihann	2015-01-28	More work done on the intital report
Snorrihann	2015-01-29	Modification of roles
Snorrihann	2015-01-29	sdfsf dfsd ds
Snorrihann	2015-01-29	Change to conflicts
Snorri Hannesson	2015-01-29	Merge pull request #1 from teamDiversity/Snorri_Conflicts
Balázs Kiss	2015-02-01	Speed model for vehicles, basic collison avoidance
Balázs Kiss	2015-02-01	Merge pull request #2 from teamDiversity/develop_speed
Snorrihann	2015-02-03	meeting 29th of january
Snorri Hannesson	2015-02-03	Merge pull request #3 from teamDiversity/meeting_log
Snorrihann	2015-02-04	Implementation of different types of vehicles
Snorrihann	2015-02-04	Changes on the initial report made by Neab
Snorri Hannesson	2015-02-04	Merge pull request #4 from teamDiversity/initialReport_NeabChanges
Snorri Hannesson	2015-02-04	Update .gitignore
Snorri Hannesson	2015-02-04	Delete initialReport.txt
Snorri Hannesson	2015-02-04	Delete initialReport.wc
Balázs Kiss	2015-02-05	Corrected my name
Balázs Kiss	2015-02-05	Merge pull request #5 from teamDiversity/report_typo
Balázs Kiss	2015-02-05	Removed junk
Balázs Kiss	2015-02-05	Merge pull request #6 from teamDiversity/report_typo
Balázs Kiss	2015-02-05	Moved vehicle classes to separate package
Balázs Kiss	2015-02-05	Use protected topSpeed field for vehicles
Snorrihann	2015-02-05	Merge branch 'develop_carsAndBuses_improvements' of https://github.com/teamDiversity/trafficSim
Snorrihann	2015-02-05	Succestions of improvements implemented
yukolthep	2015-02-05	first gui implementation

Balázs Kiss	2015-02-05	Merge pull request #9 from teamDiversity/master
Snorrihann	2015-02-05	meeting 5th of feb
Snorri Hannesson	2015-02-05	Merge pull request #7 from teamDiversity/develop_carsAndBuses_improvements
Snorri Hannesson	2015-02-05	Merge pull request #10 from teamDiversity/develop_carsAndBuses
Snorrihann	2015-02-05	Merge branch 'master' of https://github.com/teamDiversity/trafficSim
Snorrihann	2015-02-05	acceleration re-changed to maxAcceleration
Snorri Hannesson	2015-02-05	Merge pull request #11 from teamDiversity/development_maxAcceleration
Snorrihann	2015-02-05	Meeting 5th feb logged
Snorri Hannesson	2015-02-05	Merge pull request #13 from teamDiversity/meeting_5thFeb
Snorrihann	2015-02-05	The mandatory/optional table and some proofreading
Balázs Kiss	2015-02-07	These files were not the latest
Balázs Kiss	2015-02-07	Merge branch 'master' into gabb_branch_merge
Balázs Kiss	2015-02-07	put back maxAcceleration
Balázs Kiss	2015-02-07	Merged vehicle subclasses
Balázs Kiss	2015-02-07	Changed project type to Java FX
Balázs Kiss	2015-02-07	Cleanup
Balázs Kiss	2015-02-07	Merge pull request #14 from teamDiversity/gabb_branch_merge
Balázs Kiss	2015-02-07	Simulation classes
Balázs Kiss	2015-02-07	Removed unnecessary parts from GUISimulation class
Balázs Kiss	2015-02-07	Merge pull request #15 from teamDiversity/simulation_classes
Balázs Kiss	2015-02-07	Small changes
Balázs Kiss	2015-02-07	Merge pull request #16 from teamDiversity/initial_report_balazs
Pongsakorn N. Riyamongkol	2015-02-08	1. This is the same as InitialReport.tex 2. If i edit, it is in this pool 3. I will put presentation slide too
Snorrihann	2015-02-09	Changes made on the meeting 9 feb
Snorri Hannesson	2015-02-09	Merge pull request #17 from teamDiversity/intialReport_changesFromMeeting9Feb
Snorrihann	2015-02-09	Meeting log 9th of feb
Snorrihann	2015-02-09	Changes made to fit requirements on the 'Nodes on the inital report'

Snorri Hannesson	2015-02-09	Merge pull request #18 from teamDiversity/meeting_9thFeb
Snorri Hannesson	2015-02-09	Merge pull request #19 from teamDiversity/intialReport_changesFromMeeting9Feb
eddymukasa	2015-02-10	UML Use case and Class diagram
eddymukasa	2015-02-10	Updates to UML Class multiplicities
eddymukasa	2015-02-10	Merge pull request #20 from teamDiversity/UMLDesigns
eddymukasa	2015-02-10	Updates to UML Class multiplicities
eddymukasa	2015-02-10	merge conflict resolution
eddymukasa	2015-02-10	new class diagram
yukolthep	2015-02-11	update on car's picture
Balázs Kiss	2015-02-11	Merge branch 'UMLDesigns'
Balázs Kiss	2015-02-11	Merge branch 'master' into develop_gui
Balázs Kiss	2015-02-11	Renderer classes, code cleanup
Balázs Kiss	2015-02-11	Fixed thread synch bug
Balázs Kiss	2015-02-11	Better map for testing
Snorrihann	2015-02-12	First tests, just for fun
Snorri Hannesson	2015-02-12	Merge pull request #22 from teamDiversity/test_basicInitialTestSuite
yukolthep	2015-02-16	draw horizontal and vertical roads, still rotated road left
Snorrihann	2015-02-18	More tests on vehicle and road system and a test suite class created
Snorri Hannesson	2015-02-18	Merge pull request #23 from teamDiversity/test_basicFunctions
Snorrihann	2015-02-18	jUnit library added to project.properties
Snorrihann	2015-02-18	jUnit library added to project.properties
Snorrihann	2015-02-18	meeting log updated
Snorri Hannesson	2015-02-18	Merge pull request #25 from teamDiversity/meeting_11feb
Snorrihann	2015-02-19	First creation of final report
Snorri Hannesson	2015-02-19	Merge pull request #26 from teamDiversity/finalReport_SnorriInitialWork
Snorri Hannesson	2015-02-19	Merge pull request #24 from teamDiversity/test_jUnitLibrary
Snorrihann	2015-02-19	meeting 19feb
Snorri Hannesson	2015-02-19	Merge pull request #27 from teamDiversity/meeting_19feb

yukolthep	2015-02-19	try some manual drawing. still have problem with wrong drawing of rotated road. The angle calculated using the formula seems to be correct but after draw the rotated rectangular with specified angle, it is not correct as the road is drawn with wrong angle. Still can't figure out what is the cause.
eddymukasa	2015-02-19	Adding driver Classes to project
eddymukasa	2015-02-19	CautiousDriver fix
yukolthep	2015-02-20	- fix drawVehicle to correctly draw car using correct angle. - Simulation2 class is used for testing different rotated roads drawing
Snorrihann	2015-02-20	Roads and lanes now have four points as a paramiter: leftStart, rightStart, leftEnd, rightEnd. Roads are initialised by the leftStart and leftEnd.
Balázs Kiss	2015-02-21	Project properties
Balázs Kiss	2015-02-21	step counter
Balázs Kiss	2015-02-21	Removed vehicle position from constructor
Balázs Kiss	2015-02-21	inherited type method
Balázs Kiss	2015-02-21	Removed lane from constructor
Balázs Kiss	2015-02-21	Removed unneded methods
Balázs Kiss	2015-02-21	Vehicles added at entrypoint
Balázs Kiss	2015-02-21	vehicles exit the system
Balázs Kiss	2015-02-21	Simualtion stops when all cars exited the system
Balázs Kiss	2015-02-21	Passing tests
Balázs Kiss	2015-02-21	Merge pull request #28 from teamDiversity/entry_and_exit_points
Balázs Kiss	2015-02-21	Merge development_widthOfLanes
Balázs Kiss	2015-02-21	Merge development_widthOfLanes
Balázs Kiss	2015-02-22	Merge branch 'development_widthOfLanes'
yukolthep	2015-02-23	- added new simple car and bus image. - draw vehicles based on their type. - fixed Normal and Cautious bus to extend from Bus class instead of Car class.
yukolthep	2015-02-23	- fixed using class instead of string to decide what type of vehicle it is
yukolthep	2015-02-23	- changed canvas size back to 800x600

yukolthep	2015-02-27	- clean up some unused test code - bug in drawing a car with wrong position possibly caused by the position of vehicle itself as the position reading from a command line is wrong. need further investigation.
Snorrihann	2015-02-28	roads and lanes tested
Snorrihann	2015-02-28	bugs fixed in Road and Lane classes
Snorrihann	2015-02-28	minor fix on Lane
eddymukasa	2015-03-01	Implementing driver logic
Pongsakorn N. Riyamongkol	2015-03-01	....
Balázs Kiss	2015-03-02	Merge branch 'finalReport_IntNeab'
Balázs Kiss	2015-03-02	Merge branch 'gui_draw_vehicles_with_correct_size'
Balázs Kiss	2015-03-02	jfxrt in project description file
Balázs Kiss	2015-03-02	Merge branch 'test_RoadsLanes'
Balázs Kiss	2015-03-02	Fixed syntax errors
Snorrihann	2015-03-02	incorrect pos when road has slope
Snorrihann	2015-03-02	centerPoints for start and end
eddymukasa	2015-03-04	driverLogic fix
Snorrihann	2015-03-04	time for vehicles in system printed in console
yukolthep	2015-03-04	- add start button - implement the program to automatically stop after closing the window
Pongsakorn N. Riyamongkol	2015-03-05	meeting 26th of feb
Pongsakorn N. Riyamongkol	2015-03-05	meeting 26th of feb logged
Snorri Hannesson	2015-03-05	Merge pull request #38 from teamDiversity/meeting_26thfeb
Pongsakorn N. Riyamongkol	2015-03-05	outline of final report
Snorri Hannesson	2015-03-05	Merge pull request #39 from teamDiversity/finalReport_NeabInitialWork
Snorrihann	2015-03-05	meeting 5th of march logged
Snorri Hannesson	2015-03-05	Merge pull request #40 from teamDiversity/meeting_5thmarch
Snorrihann	2015-03-05	cleanup
Snorri Hannesson	2015-03-05	Merge pull request #41 from teamDiversity/snorri_cleanup

Balázs Kiss	2015-03-06	Merge commit 'c12333d2b4a4e92263268e834ad0e56c0417e108'
Balázs Kiss	2015-03-06	Merge branch 'master' into driver_logic_merge
Balázs Kiss	2015-03-06	updated gitignore file
Balázs Kiss	2015-03-06	Fixing incompatibilities
Balázs Kiss	2015-03-06	Default constructor for vehicles
Balázs Kiss	2015-03-06	format code
Balázs Kiss	2015-03-06	Merge commit '8f5224a3bfea688218a80388091d5406e923f386'
Balázs Kiss	2015-03-06	formatting
Balázs Kiss	2015-03-06	Renamed package
Balázs Kiss	2015-03-06	Removed private netbeans files
Balázs Kiss	2015-03-06	Default speeds
Balázs Kiss	2015-03-06	Removed unused imports
Balázs Kiss	2015-03-06	Removed vehicle properties from driver classes
Balázs Kiss	2015-03-07	Moved decision methods to driver
Balázs Kiss	2015-03-07	driver dependant deceleration
Balázs Kiss	2015-03-07	dont round new positions
Balázs Kiss	2015-03-07	draw lanes
Balázs Kiss	2015-03-07	Added basic classes
Balázs Kiss	2015-03-07	steppable, traffic light states
Balázs Kiss	2015-03-07	add junctions to simulation
Balázs Kiss	2015-03-08	Merge branch 'master' into gui_create_start_button_merge
yukolthep	2015-03-08	- change draw road to fillPolygon() which does not need to calculate anything
yukolthep	2015-03-08	- edit car and bus images (rotate 90 deg) - made getDisplacementVector() public for using in SimulationRenderer class - implement new way to draw vehicles - add angleVectorDegree which returns in degree instead of radian
yukolthep	2015-03-08	- remove testing code
yukolthep	2015-03-08	Merge pull request #43 from teamDiversity/gui_rework_on_drawing
yukolthep	2015-03-08	- add a new class which will show a result of a simulation (left blank for now)
Snorri Hannesson	2015-03-08	Merge pull request #44 from teamDiversity/gui_add_more_user_interface

yukolthep	2015-03-08	- add radio buttons group to specify policy to be used - add textbox for user to enter duration of a simulation - add combobox for user to choose from pre-defined maps
yukolthep	2015-03-08	Merge pull request #45 from teamDiversity/gui_add_more_user_interface
yukolthep	2015-03-08	- add show result button
Snorri Hannesson	2015-03-08	Merge pull request #46 from teamDiversity/gui_add_result_window_button
Snorrihann	2015-03-08	results
Snorri Hannesson	2015-03-08	Merge pull request #47 from teamDiversity/development_results
Snorrihann	2015-03-11	Chapter Related work written
Snorri Hannesson	2015-03-11	Merge pull request #49 from teamDiversity/finalReport_ChapterRelatedWork_1
Balázs Kiss	2015-03-12	merged tex file
Snorrihann	2015-03-12	appendix change
Snorri Hannesson	2015-03-12	Merge pull request #52 from teamDiversity/finalReport_appendixtemplatechange

B Source Code

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator;

import javafx.application.Application;
import javafx.application.Platform;
import javafx.collections.FXCollections;
import javafx.collections.ObservableList;
import javafx.event.ActionEvent;
import javafx.event.EventHandler;
import javafx.geometry.Insets;
import javafx.scene.Scene;
import javafx.scene.canvas.Canvas;
import javafx.scene.canvas.GraphicsContext;
import javafx.scene.control.Button;
import javafx.scene.control.ComboBox;
import javafx.scene.control.RadioButton;
import javafx.scene.control.TextField;
import javafx.scene.control.ToggleGroup;
import javafx.scene.layout.BorderPane;
import javafx.scene.layout.HBox;
import javafx.scene.layout.Pane;
import javafx.scene.layout.StackPane;
import javafx.scene.layout.VBox;
import javafx.scene.paint.Color;
import javafx.scene.text.Text;
import javafx.stage.Stage;
import javafx.stage.WindowEvent;
import trafficsimulator.gui.SimulationRenderer;
import trafficsimulator.gui.SimulationResults;
import trafficsimulator.simulations.Simulation1;
import trafficsimulator.simulations.Simulation2;

/**
 *
 * @author balazs
 */
public class TrafficSimulator extends Application {

  @Override
  public void start(final Stage primaryStage) {

    //main layout
    BorderPane root = new BorderPane();
    //canvas layout (white bg)
    StackPane canvas_holder = new StackPane();
    canvas_holder.setStyle("-fx-background-color: white");
    //create a control panel
    StackPane control_panel = new StackPane();
    control_panel.setStyle("-fx-backgrond-color: blue");
    //create canvas
    Canvas canvas = new Canvas(800,600);
    //add canvas to its holder
    canvas_holder.getChildren().add(canvas);
    //create a GraphicsContext
    GraphicsContext gc = canvas.getGraphicsContext2D();
```

```
    //add canvas layout into main layout
    root.setLeft(canvas_holder);
    //create set of option selectors (buttons, textfields, radio buttons...)
    final Button startSim = new Button("Start");
    startSim.setPrefSize(100, 50);
    BorderPane button_pane = new BorderPane();
    final Button showResults = new Button("Result");
    showResults.setPrefSize(100, 50);
    //showResults.setDisable(true);
    HBox button_box = new HBox();
    button_box.setPadding(new Insets(10,15,10,15));
    button_box.setSpacing(25);
    button_box.getChildren().addAll(startSim, showResults);
    button_pane.setCenter(button_box);


    ToggleGroup policies_selector = new ToggleGroup();
    RadioButton fixed_time = new RadioButton("Fixed time policy");
    RadioButton congestion_control = new RadioButton("Congestion control policy");
    fixed_time.setToggleGroup(policies_selector);
    congestion_control.setToggleGroup(policies_selector);
    fixed_time.setSelected(true);
    VBox policy_radio_box = new VBox();
    policy_radio_box.setSpacing(15);
    policy_radio_box.getChildren().addAll(fixed_time, congestion_control);
    HBox policy_box = new HBox();
    policy_box.setPadding(new Insets(10,15,10,15));
    policy_box.setSpacing(10);
    policy_box.getChildren().add(new Text("Policy: "));
    policy_box.getChildren().add(policy_radio_box);

    HBox duration_box = new HBox();
    duration_box.setPadding(new Insets(10,15,10,15));
    duration_box.setSpacing(10);
    duration_box.getChildren().add(new Text("Duration: "));
    TextField duration_field = new TextField();
    duration_box.getChildren().add(duration_field);
    duration_box.getChildren().add(new Text("seconds"));

    HBox map_box = new HBox();
    map_box.setPadding(new Insets(10,15,10,15));
    map_box.setSpacing(10);
    map_box.getChildren().add(new Text("Map: "));
    ObservableList<String> options = FXCollections.observableArrayList("Map 1","
Map 2","Map 3");
    ComboBox map_list = new ComboBox(options);
    map_list.setValue("Map 1");
    map_box.getChildren().add(map_list);


    VBox container = new VBox();
    container.setPadding(new Insets(10,15,10,15));
    container.setSpacing(15);
    container.getChildren().addAll(policy_box, duration_box, map_box, button_pan
e);
    //add control panel into main layout
    root.setCenter(container);
    //create simulation
    final Simulation1 simulation = new Simulation1();
```

```
    SimulationRenderer renderer = new SimulationRenderer(gc, simulation);
    simulation.setRenderer(renderer);
    //simulation.start();

    //add function to option selectors
    startSim.setOnAction(new EventHandler<ActionEvent>() {

        @Override
        public void handle(ActionEvent event) {
            simulation.start();
            startSim.setDisable(true);
        }
    });
    showResults.setOnAction(new EventHandler<ActionEvent>(){

        @Override
        public void handle(ActionEvent event){
          new SimulationResults(primaryStage, simulation);
          showResults.setDisable(true);
        }
    });
    //set stage config
    primaryStage.setOnCloseRequest(new EventHandler<WindowEvent>() {

        @Override
        public void handle(WindowEvent event) {
            System.exit(0);
        }
    });
    primaryStage.setTitle("TrafficSimulator");
    primaryStage.setScene(new Scene(root,1200,700,Color.LIGHTGRAY));
    //show stage
    primaryStage.show();

  }

  /**
   * @param args the command line arguments
   */
  public static void main(String[] args) {
    launch(args);
  }

}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

/**
 *
 * @author Eddy
 */
public abstract class Driver {

  protected String name;
  protected Vehicle vehicle;

  public Driver(String name){
    this.name = name;
  }

  public void setVehicle(Vehicle vehicle){
    this.vehicle = vehicle;
  }

  abstract public double getOptimalDeceleration();

  public double getOptimalSpeedForDistance(double distance) {
    double speed = getOptimalDeceleration() * distance;

    // Capping for max speed
    if (speed > vehicle.getTopSpeed()) {
      speed = vehicle.getTopSpeed();
    }

    return speed;
  }

  public double getOptimalFollowingDistance() {
    double stoppingDistance = vehicle.getCurrentSpeed() / getOptimalDeceleration
();
    return 30.0 + stoppingDistance;
  }

  public boolean AccelerationStatus(double currentSpeed, double optimalFollowing
Dist, double distanceFromNextVechicle, double distanceFromEOLane) {
    boolean choice;
    //no car ahead
    if (distanceFromEOLane == Double.MAX_VALUE) {
      choice = true;
    }
    if (distanceFromNextVechicle <= optimalFollowingDist) {
      choice = false;
    } else {
      choice = true;
    }

    return choice;
  }
```

```
  public boolean DecelerationStatus(double currentSpeed, double optimalFollowing
Dist, double distanceFromNextVechicle, double distanceFromEOLane) {
    boolean choice;
    if (distanceFromEOLane == Double.MAX_VALUE) {
      //This will depend on the state of the traffic light
    }
    if (distanceFromNextVechicle <= optimalFollowingDist) {
      choice = true;
    } else {
      choice = false;
    }

    return choice;

  }

}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

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

/**
 *
 * @author balazs
 */
public class EntryPoint implements ISteppable{

  private Lane lane;
  private Map<Long, List<Vehicle>> steps = new HashMap<>();
  private Map<Vehicle, Long> vehicles = new HashMap<>();

  public EntryPoint(Lane lane) {
    this.lane = lane;
  }

  public Lane getLane() {
    return lane;
  }

  public void addVehicle(Vehicle vehicle, long step) {
    vehicles.put(vehicle, step);

    List stepList = steps.get(step);
    if (stepList == null) {
      stepList = new ArrayList<Vehicle>();
      steps.put(step, stepList);
    }
    stepList.add(vehicle);
    vehicle.startTime = System.currentTimeMillis();
  }

  public int numberOfVehicles() {
    return vehicles.size();
  }

  public void step(long step) {
    List<Vehicle> vehiclesForStep = steps.get(step);
    if (vehiclesForStep == null) {
      return;
    }
    for (Vehicle vehicle : vehiclesForStep) {
      //Add vehicle to system
      System.out.println(vehicle + " entered the system");
      vehicle.setLane(lane);
    }
  }
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import java.util.ArrayList;
import java.util.List;

/**
 *
 * @author balazs
 */
public class ExitPoint {

  private Lane lane;
  private List<Vehicle> vehicles = new ArrayList<>();

  ExitPoint(Lane lane) {
    this.lane = lane;
  }

  public int numberOfVehicles() {
    return vehicles.size();
  }

  void addVehicle(Vehicle vehicle) {
    System.out.println(vehicle + " exited the system");
    vehicles.add(vehicle);
    vehicle.endTime = System.currentTimeMillis();
  }
}
```

```java
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

/**
 *
 * @author balazs
 */
public interface ISteppable {
  public void step(long step);
}
```

```java
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import java.util.ArrayList;
import java.util.HashMap;
import java.util.List;

/**
 *
 * @author balazs
 */
public abstract class Junction implements ISteppable{

  private HashMap<Lane, List<Lane>> connections;

  public Junction() {
    connections = new HashMap<>();
  }

  public void connect(Lane source, Lane destination) {
    if (!connections.containsKey(source)) {
      connections.put(source, new ArrayList<Lane>());
    }
    List<Lane> lanes = connections.get(source);
    lanes.add(destination);
    source.setJunction(this);
  }

  public List<Lane> getConnectedLanes(Lane lane) {
    return connections.get(lane);
  }

  public boolean shouldVehicleEnterJunction(Vehicle vehicle){
    return true;
  }
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import java.util.ArrayList;
import java.util.List;
import trafficsimulator.utils.Point;

/**
 *
 * @author balazs
 */
public class Lane {

  public static double laneWidth = 22;

  public enum Direction {

    IDENTICAL, OPPOSITE
  }

  private Road road;
  private List<Vehicle> vehicles = new ArrayList<>();
  private Junction junction;
  private Direction direction;
  private ExitPoint exitPoint;

  public Lane(Direction direction) {
    this.direction = direction;
    exitPoint = new ExitPoint(this);
  }

  public void enter(Vehicle vehicle) {
    vehicles.add(vehicle);
  }

  public void exit(Vehicle vehicle) {
    vehicles.remove(vehicle);
  }

  public Junction getJunction() {
    return junction;
  }

  public void setJunction(Junction junction) {
    this.exitPoint = null;
    this.junction = junction;
  }

  public ExitPoint getExitPoint() {
    return exitPoint;
  }

  public Road getRoad() {
    return road;
  }
```

```
  public void setRoad(Road road) {
    this.road = road;
  }

  public Direction getDirection() {
    return direction;
  }

  public void setDirection(Direction direction) {
    this.direction = direction;
  }

  public Point getLeftStartPoint() {
    Road road = getRoad();
    int pos = road.getLaneIndexPosition(this);
    if (getDirection() == Direction.IDENTICAL) {
      return road.getLeftStartPoint().plus(acrossLaneVector().mult(pos));
    } else {
      return road.getLeftEndPoint().minus(acrossLaneVector().mult(pos + 1));
    }
  }

  public Point getLeftEndPoint() {
    Road road = getRoad();
    int pos = road.getLaneIndexPosition(this);
    if (getDirection() == Direction.IDENTICAL) {
      return road.getLeftEndPoint().plus(acrossLaneVector().mult(pos));
    } else {
      return road.getLeftStartPoint().minus(acrossLaneVector().mult((pos + 1)));
    }
  }

  private Point calculateRightPoints(Point p) {
    return p.plus(acrossLaneVector());
  }

  public Point getRightStartPoint() {
    return calculateRightPoints(getLeftStartPoint());
  }

  public Point getRightEndPoint() {
    return calculateRightPoints(getLeftEndPoint());
  }

  public Point getCenterStartPoint() {
    return (getLeftStartPoint().plus(getRightStartPoint())).div(2);
  }

  public Point getCenterEndPoint() {
    return (getLeftEndPoint().plus(getRightEndPoint())).div(2);
  }

  public Point getDirectionVector() {
    Road road = getRoad();
    if (getDirection() == Direction.IDENTICAL) {
      return road.getLeftEndPoint().minus(road.getLeftStartPoint());
    } else {
      return road.getLeftStartPoint().minus(road.getLeftEndPoint());
```

```
    }
  }

  private Point acrossLaneUnitVector() {
    Point dir = getDirectionVector();
    Point unitDir = dir.div(dir.distanceFromOrigin());
    Point rotateUnitDir = unitDir.rotateVector(Math.PI / 2);
    return rotateUnitDir;
  }

  private Point acrossLaneVector() {
    double x = Math.floor(laneWidth * Math.cos(acrossLaneUnitVector().angleVecto
r()));
    double y = Math.floor(laneWidth * Math.sin(acrossLaneUnitVector().angleVecto
r()));
    return new Point(x, y);
  }

  public double getDistanceFromNextVehicle(Vehicle vehicle) {
    double minDistance = Double.MAX_VALUE;

    for (Vehicle v : vehicles) {
      if (vehicle == v) {
        continue;
      }

      double distance = vehicle.getPosition().distance(v.getPosition());
      if (distance < minDistance) {
        Point dir = v.getPosition().minus(vehicle.getPosition());
        if (dir.inSameQuadrant(getDirectionVector())) {
          minDistance = distance;
        }
      }
    }

    return minDistance;
  }

}
```

```java
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import java.util.ArrayList;
import java.util.List;

/**
 *
 * @author balazs
 */
public class Map {

  private List<Road> roads;
  private List<Junction> junctions;

  public Map() {
    roads = new ArrayList<>();
    junctions = new ArrayList<>();
  }

  public List<Road> getRoads() {
    return roads;
  }

  public void addRoad(Road road) {
    roads.add(road);
  }

  public List<Junction> getJunctions() {
    return junctions;
  }

  public void addJunction(Junction junction) {
    junctions.add(junction);
  }

}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import java.util.ArrayList;
import java.util.List;
import trafficsimulator.utils.Point;

/**
 *
 * @author balazs
 */
public class Road {

  private List<Lane> lanes;
  //The road is initialised by specifying the left paramiters of the road.
  //Each lane will be added to the right these paramiters and the right
  //paramiters of the road will be calculated by the numbers of lanes on the roa
d.
  private Point leftStartPoint;
  private Point leftEndPoint;

  public Road(Point leftStartPoint, Point leftEndPoint) {
    lanes = new ArrayList<>();
    this.leftStartPoint = leftStartPoint;
    this.leftEndPoint = leftEndPoint;
  }

  public void addLane(Lane lane) {
    lanes.add(lane);
    lane.setRoad(this);
  }

  public List<Lane> getLanes() {
    return lanes;
  }

  public void setLanes(List<Lane> lanes) {
    this.lanes = lanes;
  }

  public Point getLeftStartPoint() {
    return leftStartPoint;
  }

  public void setLeftStartPoint(Point leftStartPoint) {
    this.leftStartPoint = leftStartPoint;
  }

  public Point getLeftEndPoint() {
    return leftEndPoint;
  }

  public void setLeftEndPoint(Point leftEndPoint) {
    this.leftEndPoint = leftEndPoint;
  }
```

```
  public Point getRandomPosition() {
    Point dir = leftEndPoint.minus(leftStartPoint);
    return leftStartPoint.plus(dir.mult(Math.random()));
  }

  public Point getDirectionVector() {
    return leftEndPoint.minus(leftStartPoint);
  }

  public int getLaneIndexPosition(Lane l) {
    return lanes.indexOf(l);
  }

  public double calculateWidth() {
    double width = 0;
    for (Lane l : lanes) {
      width += Lane.laneWidth;
    }
    return width;
  }

  private Point acrossRoadUnitVector() {
    Point dir = getDirectionVector();
    Point unitDir = dir.div(dir.distanceFromOrigin());
    Point rotateUnitDir = unitDir.rotateVector(Math.PI / 2);
    return rotateUnitDir;
  }

  private Point acrossRoadVector() {
    double x = Math.round(calculateWidth() * Math.cos(acrossRoadUnitVector().ang
leVector()));
    double y = Math.round(calculateWidth() * Math.sin(acrossRoadUnitVector().ang
leVector()));
    return new Point(x, y);
  }

  public Point getRightStartPoint() {
    Point rightStartPoint = leftStartPoint.plus(acrossRoadVector());
    return rightStartPoint;
  }

  public Point getRightEndPoint() {
    Point rightEndPoint = leftEndPoint.plus(acrossRoadVector());
    return rightEndPoint;
  }
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import java.util.ArrayList;
import java.util.Date;
import java.util.List;
import java.util.Timer;
import java.util.TimerTask;
import javafx.scene.text.Text;
import trafficsimulator.gui.IRenderer;

/**
 *
 * @author balazs
 */
public abstract class Simulation extends TimerTask {

  private long stepCounter = 0;
  protected Timer timer = new Timer();
  protected Map map = new Map();
  protected List<Vehicle> vehicles = new ArrayList<>();
  protected List<EntryPoint> entryPoints = new ArrayList<>();
  protected List<ExitPoint> exitPoints = new ArrayList<>();
  protected IRenderer renderer;

  public Simulation() {

  }

  public Simulation(IRenderer renderer) {
    this.renderer = renderer;
  }

  protected abstract void init();

  @Override
  public void run() {

    stepCounter++;
    System.out.println("Step " + stepCounter);

    if (numberOfVehiclesAtExitPoints() == vehicles.size()) {
      printStats();
      System.out.println("Simulation end");
      timer.cancel();
      return;
    }

    for (ISteppable ep : entryPoints) {
      ep.step(stepCounter);
    }

    for (ISteppable junction : map.getJunctions()) {
      junction.step(stepCounter);
    }
```

```
    for (ISteppable vehicle : getVehicles()) {
      vehicle.step(stepCounter);
    }

    if (renderer != null) {
      renderer.render();
    }
  }

  private EntryPoint getEntryPointForLane(Lane lane) {
    for (EntryPoint ep : entryPoints) {
      if (ep.getLane() == lane) {
        return ep;
      }
    }
    EntryPoint ep = new EntryPoint(lane);
    entryPoints.add(ep);
    return ep;
  }

  protected void addVehicle(Vehicle vehicle, Lane lane, long step) {
    EntryPoint ep = getEntryPointForLane(lane);
    ep.addVehicle(vehicle, step);
    vehicles.add(vehicle);
  }

  private List<ExitPoint> getExitPoints() {
    List<ExitPoint> exitPoints = new ArrayList<>();
    for (Road road : getMap().getRoads()) {
      for (Lane lane : road.getLanes()) {
        ExitPoint ep = lane.getExitPoint();
        if (ep == null) {
          continue;
        }
        exitPoints.add(ep);
      }
    }
    return exitPoints;
  }

  private int numberOfVehiclesAtExitPoints() {
    int n = 0;
    for (ExitPoint ep : exitPoints) {
      n += ep.numberOfVehicles();
    }
    return n;
  }

  public void start() {
    init();
    this.exitPoints = getExitPoints();
    timer.scheduleAtFixedRate(this, 0, 100);
  }

  public IRenderer getRenderer() {
    return renderer;
  }
```

```
  public void setRenderer(IRenderer renderer) {
    this.renderer = renderer;
  }

  public Map getMap() {
    return map;
  }

  public List<Vehicle> getVehicles() {
    List<Vehicle> vehiclesInSystem = new ArrayList<>();
    for (Vehicle vehicle : vehicles) {
      if (!vehicle.isInSystem()) {
        continue;
      }
      vehiclesInSystem.add(vehicle);
    }
    return vehiclesInSystem;
  }

  public List<Vehicle> getExitedVehicles() {
    List<Vehicle> vehiclesInSystem = new ArrayList<>();
    for (Vehicle vehicle : vehicles) {
      if (vehicle.isInSystem()) {
        continue;
      }
      vehiclesInSystem.add(vehicle);
    }
    return vehiclesInSystem;
  }

  public void printStats() {
    for (Vehicle vehicle : getExitedVehicles()) {
      System.out.println(vehicle.getType() + " was in the system for " + vehicle.timeSpe
ntInSystem() + " seconds");
    }
  }

  public Text averageTime() {
    double total = 0;
    double average = 0;
    for (Vehicle vehicle : getExitedVehicles()) {
      total += vehicle.timeSpentInSystem();
    }
    average = total/getExitedVehicles().size();

    if ( getExitedVehicles().isEmpty() ) return new Text("Average time: 0");
    else return new Text(String.valueOf("Average time: " + average));
  }

  public Text longestTime() {
    double longest = 0;
    for (Vehicle vehicle : getExitedVehicles()) {
      if (longest < vehicle.timeSpentInSystem()) {
        longest = vehicle.timeSpentInSystem();
      }
    }
    if ( getExitedVehicles().isEmpty() ) return new Text("Longest time: 0");
    else return new Text(String.valueOf("Longest time: " + longest));
  }
```

```
  public Text shortestTime() {
    double shortest = Integer.MAX_VALUE;
    for (Vehicle vehicle : getExitedVehicles()) {
      if (shortest > vehicle.timeSpentInSystem()) {
        shortest = vehicle.timeSpentInSystem();
      }
    }
    if ( getExitedVehicles().isEmpty() ) return new Text("Shortest time: 0");
    else return new Text(String.valueOf("Shortest time: " + shortest));
  }
}
```

```java
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

/**
 *
 * @author balazs
 */
public class TrafficSimulator {

  /**
   * @param args the command line arguments
   */
  public static void main(String[] args) {

  }

}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import java.util.List;
import java.util.Random;
import trafficsimulator.utils.Point;
import trafficsimulator.utils.Size;

/**
 *
 * @author balazs
 */
public abstract class Vehicle implements ISteppable{

  private Lane lane;
  private Point position;
  private double currentSpeed = 0;
  protected double topSpeed;
  protected double maxAcceleration;
  protected double maxDeceleration;
  protected double optimalDeceleration;
  protected Size size;
  protected Driver driver;
  protected boolean accelerate;
  protected boolean decelerate;

  protected String type = "Vehicle Base Object";
  public long startTime = 0;
  public long endTime = 0;

  public Vehicle(Driver driver) {
    this.currentSpeed = 0;
    if (driver == null) {
      this.driver = NormalDriver("Default Driver");
    } else {
      this.driver = driver;
    }
    this.driver.setVehicle(this);
  }

  public Size getSize() {
    return size;
  }

  public double getTopSpeed() {
    return topSpeed;
  }

  public double getMaxAcceleration() {
    return maxAcceleration;
  }

  public double getMaxDeceleration() {
    return maxDeceleration;
  }
```

```
  public String getType() {
    return type;
  }

  public Point getPosition() {
    return position;
  }

  public Lane getLane() {
    return lane;
  }

  public boolean isInSystem() {
    return lane != null;
  }

  public void setLane(Lane lane) {
    if (lane == null) {
      this.lane = null;
      return;
    }
    if (!isInSystem()) {
      this.position = lane.getCenterStartPoint();
    }
    this.lane = lane;
    this.lane.enter(this);
  }

  public double getCurrentSpeed() {
    return currentSpeed;
  }

  private void setCurrentSpeed(double speed) {
    if (speed > getTopSpeed()) {
      currentSpeed = getTopSpeed();
    } else if (speed < 0) {
      currentSpeed = 0;
    } else {
      currentSpeed = speed;
    }
  }

  private double getDistanceFromEOLane() {

    double distance = getLane().getLeftEndPoint().distance(this.getPosition());
    return distance;
  }

  private void changeSpeed() {
    accelerate = driver.AccelerationStatus(this.currentSpeed, driver.getOptimalF
ollowingDistance(), getLane().getDistanceFromNextVehicle(this), getDistanceFromE
OLane());
    decelerate = driver.DecelerationStatus(this.currentSpeed, driver.getOptimalF
ollowingDistance(), getLane().getDistanceFromNextVehicle(this), getDistanceFromE
OLane());

    if (accelerate) {
      accelerate();
```

```
    } else if (decelerate) {
      decelerate();
    } else {
      currentSpeed = currentSpeed;
    }
  }

  private boolean leftRoad(Point oldPosition, Point newPosition) {
    Point endPoint = lane.getCenterEndPoint();
    if (oldPosition.getX() <= endPoint.getX() && newPosition.getX() > endPoint.g
etX()) {
      return true;
    }
    if (oldPosition.getX() >= endPoint.getX() && newPosition.getX() < endPoint.g
etX()) {
      return true;
    }
    if (oldPosition.getY() <= endPoint.getY() && newPosition.getY() > endPoint.g
etY()) {
      return true;
    }
    if (oldPosition.getY() >= endPoint.getY() && newPosition.getY() < endPoint.g
etY()) {
      return true;
    }
    return false;
  }

  private Lane chooseRandomNewLane() {
    Junction junction = lane.getJunction();
    if (junction == null) {
      return null;
    }
    List<Lane> lanes = junction.getConnectedLanes(lane);
    if (lanes.isEmpty()) {
      return null;
    }
    Random randomGenerator = new Random();
    int index = randomGenerator.nextInt(lanes.size());
    return lanes.get(index);
  }

  public Point getDisplacementVector() {
    Point dir = getLane().getDirectionVector();
    Point unitDir = dir.div(dir.distanceFromOrigin());
    double x = getCurrentSpeed() * Math.cos(unitDir.angleVector());
    double y = getCurrentSpeed() * Math.sin(unitDir.angleVector());
    return new Point(x, y);
  }

  public double timeSpentInSystem() {
    return (endTime - startTime) / 1000;
  }

  public void step(long stepCounter) {
    System.out.print(getType() + "#" + hashCode());

    // Change speed of vehicle
    changeSpeed();
```

```
    // Calculate new position
    Point newPosition = position.plus(getDisplacementVector());

    // Check if vehicle has to change lane
    if (leftRoad(this.position, newPosition)) {
      // Move vehicle to random next lane
      Lane newLane = chooseRandomNewLane();
      if (newLane != null) {
        this.lane.exit(this);
        this.position = newLane.getCenterStartPoint();
        this.setLane(newLane);
      } else {
        this.lane.exit(this);
        this.lane.getExitPoint().addVehicle(this);
        this.setLane(null);
      }
    } else {
      //Move vehicle
      position = newPosition;
    }

    System.out.println(" position: " + Math.round(position.getX()) + "," + Math.roun
d(position.getY()) + " speed: " + Math.round(currentSpeed));
  }

  protected void accelerate() {
    double dist = getLane().getDistanceFromNextVehicle(this) - driver.getOptimal
FollowingDistance();

    double optimalSpeed = driver.getOptimalSpeedForDistance(dist);

    if (optimalSpeed > getCurrentSpeed()) {
      double speedDifference = optimalSpeed - getCurrentSpeed();
      if (speedDifference < getMaxAcceleration()) {
        setCurrentSpeed(getCurrentSpeed() + speedDifference);
      } else {
        setCurrentSpeed(getCurrentSpeed() + getMaxAcceleration());
      }
    }
  }

  protected void decelerate() {

    double dist = getLane().getDistanceFromNextVehicle(this) - driver.getOptimal
FollowingDistance();

    double optimalSpeed = driver.getOptimalSpeedForDistance(dist);

    if (optimalSpeed < getCurrentSpeed()) {
      double speedDifference = getCurrentSpeed() - optimalSpeed;
      if (speedDifference < getMaxDeceleration()) {
        setCurrentSpeed(getCurrentSpeed() - speedDifference);
      } else {
        setCurrentSpeed(getCurrentSpeed() - getMaxDeceleration());
      }
    }
  }
```

```
  private Driver NormalDriver(String default_Driver) {
    throw new UnsupportedOperationException("Not supported yet."); //To change body o
f generated methods, choose Tools | Templates.
  }


}
```

```java
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.drivers;

import trafficsimulator.core.Driver;
import trafficsimulator.vehicles.Bus;
import trafficsimulator.vehicles.Car;

/**
 *
 * @author Eddy
 */
public class CautiousDriver extends Driver {

  public CautiousDriver(String name) {
    super(name);
  }

  @Override
  public double getOptimalDeceleration() {
    if (Car.class.isInstance(vehicle)) {
      return 3;
    } else if (Bus.class.isInstance(vehicle)) {
      return 2;
    } else {
      return 1;
    }
  }

}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.drivers;

import trafficsimulator.core.Driver;
import trafficsimulator.vehicles.Bus;
import trafficsimulator.vehicles.Car;

/**
 *
 * @author Eddy
 */
public class NormalDriver extends Driver {

  public NormalDriver(String name) {

    super(name);
  }

  @Override
  public double getOptimalDeceleration() {
    if (Car.class.isInstance(vehicle)) {
      return 3;
    } else if (Bus.class.isInstance(vehicle)) {
      return 2;
    } else {
      return 1;
    }
  }
}
```

```java
/*
 * To change this license header, choose License Headers in Project Properties.
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 * and open the template in the editor.
 */
package trafficsimulator.drivers;

import trafficsimulator.core.Driver;
import trafficsimulator.vehicles.Bus;
import trafficsimulator.vehicles.Car;

/**
 *
 * @author Eddy
 */
public class RecklessDriver extends Driver {

  public RecklessDriver(String name) {

    super(name);
  }

  @Override
  public double getOptimalDeceleration() {
    if (Car.class.isInstance(vehicle)) {
      return 3;
    } else if (Bus.class.isInstance(vehicle)) {
      return 2;
    } else {
      return 1;
    }
  }
}
```

```java
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.gui;

/**
 *
 * @author balazs
 */
public interface IRenderer {

  public void render();
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.gui;

import java.util.List;
import java.util.concurrent.Executors;
import java.util.concurrent.ScheduledExecutorService;
import java.util.concurrent.TimeUnit;
import javafx.animation.FillTransition;
import javafx.animation.ParallelTransition;
import javafx.animation.RotateTransition;
import javafx.animation.ScaleTransition;
import javafx.animation.Timeline;
import javafx.animation.TranslateTransition;
import javafx.application.Application;
import javafx.application.Platform;
import javafx.event.ActionEvent;
import javafx.event.EventHandler;
import javafx.scene.*;
import javafx.scene.canvas.Canvas;
import javafx.scene.canvas.GraphicsContext;
import javafx.scene.control.Button;
import javafx.scene.image.Image;
import javafx.scene.layout.BorderPane;
import javafx.scene.layout.StackPane;
import javafx.scene.paint.Color;
import javafx.scene.shape.Rectangle;
import javafx.scene.transform.Rotate;
import javafx.stage.Stage;
import javafx.util.Duration;
import trafficsimulator.core.Lane;

import trafficsimulator.core.Lane.Direction;
import trafficsimulator.core.Road;
import trafficsimulator.core.Simulation;
import trafficsimulator.core.Vehicle;
import trafficsimulator.utils.Point;
import trafficsimulator.vehicles.Bus;
import trafficsimulator.vehicles.Car;

/**
 *
 * @author yukolthep
 */
public class SimulationRenderer implements IRenderer {

  private Stage stage;
  private Simulation simulation;
  private GraphicsContext gc;

  Image car_image = new Image("pic/car_tran.gif", 20, 0, true, false);
  Image car = new Image("pic/car.jpg");
  Image bus = new Image("pic/bus.jpg");

  public SimulationRenderer(GraphicsContext gc, Simulation simulation) {
    this.stage = stage;
```

```
    this.simulation = simulation;
    this.gc = gc;
  }

  public void render() {
    Platform.runLater(new Runnable() {

      @Override
      public void run() {
        clear();
        drawRoads();
        drawLanes();
        drawVehicles();
      }
    });

  }

  /*Clear canvas before painting updated components*/
  private void clear() {
    gc.clearRect(0, 0, 700, 700);
  }

  private void drawRoads() {
    List<Road> roads = this.simulation.getMap().getRoads();
    for (Road road : roads) {
      Point leftStartPoint = road.getLeftStartPoint();
      Point rightStartPoint = road.getRightStartPoint();
      Point leftEndPoint = road.getLeftEndPoint();
      Point rightEndPoint = road.getRightEndPoint();
      gc.setFill(Color.GRAY);
      gc.fillPolygon(new double[] {leftStartPoint.getX(),leftEndPoint.getX(),rig
htEndPoint.getX(),rightStartPoint.getX()}, new double[] {leftStartPoint.getY(),
leftEndPoint.getY(), rightEndPoint.getY(), rightStartPoint.getY()}, 4);
    }
  }

  private void drawLanes(){
    List<Road> roads = this.simulation.getMap().getRoads();
    for (Road road : roads) {
      List<Lane> lanes = road.getLanes();
      for (int index = 0 ; index < lanes.size()-1 ; index++) {
        Lane lane = lanes.get(index);
        Point leftStartPoint = lane.getLeftStartPoint();
        Point leftEndPoint = lane.getLeftEndPoint();
        Point rightStartPoint = lane.getRightStartPoint();
        Point rightEndPoint = lane.getRightEndPoint();
        gc.setLineWidth(1);
        gc.setStroke(Color.BLACK);
        if(index == lanes.size()-1){
          break;
        }
        if(lane.getDirection() == Direction.IDENTICAL){
          gc.strokeLine(rightStartPoint.getX(), rightStartPoint.getY(), rightEnd
Point.getX(), rightEndPoint.getY());
        }else{
          gc.strokeLine(leftStartPoint.getX(), leftStartPoint.getY(), leftEndPoi
nt.getX(), leftEndPoint.getY());
        }
```

```
      }
    }
  }

  private void drawVehicles() {
    List<Vehicle> vehicles = this.simulation.getVehicles();
    for (Vehicle vehicle : vehicles) {
      if (Car.class.isInstance(vehicle)) {
        Double angle = vehicle.getDisplacementVector().angleVectorDegree();
        drawRotatedImage(gc, car, angle, (vehicle.getPosition().getX() − car.get
Width() / 2), (vehicle.getPosition().getY() − car.getHeight() / 2));
      }else if (Bus.class.isInstance(vehicle)) {
        Double angle = vehicle.getDisplacementVector().angleVectorDegree();
        drawRotatedImage(gc, bus, angle, (vehicle.getPosition().getX() − bus.get
Width() / 2), (vehicle.getPosition().getY() − bus.getHeight() / 2));
      }
    }
  }


  private void rotate(GraphicsContext gc, double angle, double px, double py) {
    Rotate r = new Rotate(angle, px, py);
    gc.setTransform(r.getMxx(), r.getMyx(), r.getMxy(), r.getMyy(), r.getTx(), r
.getTy());
  }

  private void drawRotatedImage(GraphicsContext gc, Image image, double angle, d
ouble tlpx, double tlpy) {
    gc.save(); // saves the current state on stack, including the current transf
orm
    rotate(gc, angle, tlpx + image.getWidth() / 2, tlpy + image.getHeight() / 2)
;
    gc.drawImage(image, tlpx, tlpy);
    gc.restore(); // back to original state (before rotation)
  }
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.gui;


import javafx.geometry.Rectangle2D;
import javafx.scene.Scene;
import javafx.scene.layout.VBox;
import javafx.scene.text.Text;
import javafx.stage.Modality;
import javafx.stage.Screen;
import javafx.stage.Stage;
import trafficsimulator.core.Simulation;

/**
 *
 * @author yukolthep
 */
public class SimulationResults extends Stage{
  public SimulationResults(Stage primaryStage, Simulation simulation){
    initModality(Modality.NONE);
    initOwner(primaryStage);
    VBox dialogVbox = new VBox(20);
    dialogVbox.getChildren().add(simulation.averageTime());
    dialogVbox.getChildren().add(simulation.longestTime());
    dialogVbox.getChildren().add(simulation.shortestTime());
    Scene dialogScene = new Scene(dialogVbox, 300, 200);
    setScene(dialogScene);
    Rectangle2D primScreenBounds = Screen.getPrimary().getVisualBounds();
    setX((primScreenBounds.getWidth() - getWidth()) / 2);
    setY((primScreenBounds.getHeight() - getHeight()) / 4);
    show();
  }
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.junctions;

import trafficsimulator.core.Lane;

/**
 *
 * @author balazs
 */
public class TrafficLight {
  public static final int GREEN_DURATION = 10;
  public static final int YELLOW_DURATION = 2;
  public static final int RED_DURATION = 10;
  public static final int REDYELLOW_DURATION = 3;

  public enum State {

    GREEN, YELLOW, RED, REDYELLOW
  }

  private State state = State.RED;
  private Lane lane;

  public TrafficLight(Lane lane){
    this.lane = lane;
  }

  public State getState() {
    return state;
  }

  public void setState(State state) {
    this.state = state;
  }

  public Lane getLane() {
    return lane;
  }

  public void nextState(){
    switch(state){
      case GREEN:
        setState(State.YELLOW);
        break;
      case YELLOW:
        setState(State.RED);
        break;
      case RED:
        setState(State.REDYELLOW);
        break;
      case REDYELLOW:
        setState(State.GREEN);
        break;
    }
  }
```

```
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.junctions;

import java.util.ArrayList;
import java.util.HashMap;
import java.util.List;
import java.util.Map;
import trafficsimulator.core.Junction;
import trafficsimulator.core.Lane;
import trafficsimulator.core.Vehicle;

/**
 *
 * @author balazs
 */
public class TrafficLightJunction extends Junction{

  private List<TrafficLight> trafficLights = new ArrayList();
  private TrafficLight activeTrafficLight;
  private int stepCounter = 0;

  private TrafficLight getTrafficLightForLane(Lane lane){
    for(TrafficLight trafficLight : trafficLights){
      if(trafficLight.getLane()==lane){
        return trafficLight;
      }
    }
    return null;
  }

  public void connect(Lane source, Lane destination) {
    super.connect(source, destination);

    if (getTrafficLightForLane(source) == null) {
      TrafficLight trafficLight = new TrafficLight(source);
      trafficLights.add(trafficLight);
    }
  }

  public boolean shouldVehicleEnterJunction(Vehicle vehicle){
    TrafficLight trafficLight = getTrafficLightForLane(vehicle.getLane());
    if(trafficLight.getState() == TrafficLight.State.GREEN){
      return true;
    }else{
      return false;
    }
  }

  private void activateTrafficLight(TrafficLight activeTrafficLight){
    // Making sure all traffic lights are red
    for(TrafficLight trafficLight : trafficLights){
      trafficLight.setState(TrafficLight.State.RED);
    }

    // Activating light
```

```
    this.activeTrafficLight = activeTrafficLight;
    activeTrafficLight.nextState();
    stepCounter = 0;
  }

  private void activateNextTrafficLight(){
    int index = trafficLights.indexOf(activeTrafficLight);
    if(index == trafficLights.size()-1){
      activateTrafficLight(trafficLights.get(0));
    }else{
      activateTrafficLight(trafficLights.get(index+1));
    }
  }

  public void step(long step) {
    if(activeTrafficLight == null){
      activateTrafficLight(trafficLights.get(0));
      return;
    }

    stepCounter++;

    if(activeTrafficLight.getState() == TrafficLight.State.GREEN && stepCounter
== TrafficLight.GREEN_DURATION){
      activeTrafficLight.nextState();
      stepCounter = 0;
    }else if(activeTrafficLight.getState() == TrafficLight.State.YELLOW && stepC
ounter == TrafficLight.YELLOW_DURATION){
      activateNextTrafficLight();
    }else if(activeTrafficLight.getState() == TrafficLight.State.REDYELLOW && st
epCounter == TrafficLight.REDYELLOW_DURATION){
      activeTrafficLight.nextState();
      stepCounter = 0;
    }else if(activeTrafficLight.getState() == TrafficLight.State.RED && stepCoun
ter == TrafficLight.RED_DURATION){
      activeTrafficLight.nextState();
      stepCounter = 0;
    }
  }
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.simulations;

import trafficsimulator.core.Driver;
import trafficsimulator.core.Junction;
import trafficsimulator.core.Lane;
import trafficsimulator.core.Road;
import trafficsimulator.core.Simulation;
import trafficsimulator.core.Vehicle;
import trafficsimulator.drivers.CautiousDriver;
import trafficsimulator.drivers.NormalDriver;
import trafficsimulator.drivers.RecklessDriver;
import trafficsimulator.junctions.TrafficLightJunction;
import trafficsimulator.utils.Point;
import trafficsimulator.vehicles.Bus;
import trafficsimulator.vehicles.Car;


/**
 *
 * @author balazs
 */
public class Simulation1 extends Simulation{

  @Override
  protected void init() {
    Road r1 = new Road(new Point(70, 20), new Point(500, 20));
    Lane l11 = new Lane(Lane.Direction.IDENTICAL);
    Lane l12 = new Lane(Lane.Direction.OPPOSITE);
    r1.addLane(l11);
    r1.addLane(l12);
    Road r2 = new Road(new Point(500, 20), new Point(500, 450));
    Lane l21 = new Lane(Lane.Direction.IDENTICAL);
    Lane l22 = new Lane(Lane.Direction.OPPOSITE);
    r2.addLane(l21);
    r2.addLane(l22);
    Road r3 = new Road(new Point(500, 450), new Point(20, 100));
    Lane l31 = new Lane(Lane.Direction.IDENTICAL);
    Lane l32 = new Lane(Lane.Direction.OPPOSITE);
    r3.addLane(l31);
    r3.addLane(l32);
    Road r4 = new Road(new Point(500, 20), new Point(600, 20));
    Lane l41 = new Lane(Lane.Direction.IDENTICAL);
    Lane l42 = new Lane(Lane.Direction.OPPOSITE);
    r4.addLane(l41);
    r4.addLane(l42);
    Road r5 = new Road(new Point(600, 20), new Point(600, 450));
    Lane l51 = new Lane(Lane.Direction.IDENTICAL);
    Lane l52 = new Lane(Lane.Direction.OPPOSITE);
    r5.addLane(l51);
    r5.addLane(l52);
    Road r6 = new Road(new Point(600, 450), new Point(500, 450));
    Lane l61 = new Lane(Lane.Direction.IDENTICAL);
    Lane l62 = new Lane(Lane.Direction.OPPOSITE);
    r6.addLane(l61);
```

```
    r6.addLane(l62);
    Road r7 = new Road(new Point(600, 450), new Point(650, 450));
    Lane l71 = new Lane(Lane.Direction.IDENTICAL);
    r7.addLane(l71);

    Junction j1 = new TrafficLightJunction();
    j1.connect(l11, l21);
    j1.connect(l11, l41);
    j1.connect(l22, l12);
    j1.connect(l22, l41);
    j1.connect(l42, l12);
    j1.connect(l42, l21);
    Junction j2 = new TrafficLightJunction();
    j2.connect(l21, l31);
    j2.connect(l21, l62);
    j2.connect(l32, l22);
    j2.connect(l32, l62);
    j2.connect(l61, l22);
    j2.connect(l61, l31);
    Junction j3 = new TrafficLightJunction();
    j3.connect(l31, l11);
    j3.connect(l12, l32);
    Junction j4 = new TrafficLightJunction();
    j4.connect(l41, l51);
    j4.connect(l52, l42);
    Junction j5 = new TrafficLightJunction();
    j5.connect(l51, l61);
    j5.connect(l51, l71);
    j5.connect(l62, l52);
    j5.connect(l62, l71);

    map.addRoad(r1);
    map.addRoad(r2);
    map.addRoad(r3);
    map.addRoad(r4);
    map.addRoad(r5);
    map.addRoad(r6);
    map.addRoad(r7);
    map.addJunction(j1);
    map.addJunction(j2);
    map.addJunction(j3);
    map.addJunction(j4);
    map.addJunction(j5);

    Driver tom = new CautiousDriver("Tom");
    Driver mary = new NormalDriver("Mary");
    Driver jerry = new RecklessDriver("Jerry");


    addVehicle(new Car(tom), l11, 1);
    addVehicle(new Bus(jerry), l11, 20);

  }

}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.simulations;

import trafficsimulator.core.Driver;
import trafficsimulator.core.Junction;
import trafficsimulator.core.Lane;
import trafficsimulator.core.Road;
import trafficsimulator.core.Simulation;
import trafficsimulator.core.Vehicle;
import trafficsimulator.drivers.CautiousDriver;
import trafficsimulator.drivers.NormalDriver;
import trafficsimulator.drivers.RecklessDriver;
import trafficsimulator.junctions.TrafficLightJunction;
import trafficsimulator.utils.Point;
import trafficsimulator.vehicles.Car;

/**
 *
 * @author yukolthep
 */
public class Simulation2 extends Simulation {


  @Override
  protected void init() {
    Road r1 = new Road(new Point(70, 300), new Point(270, 100));
    Lane l11 = new Lane(Lane.Direction.IDENTICAL);
    Lane l12 = new Lane(Lane.Direction.OPPOSITE);
    r1.addLane(l11);
    r1.addLane(l12);
    Road r2 = new Road(new Point(270, 100), new Point(470, 300));
    Lane l21 = new Lane(Lane.Direction.IDENTICAL);
    Lane l22 = new Lane(Lane.Direction.OPPOSITE);
    r2.addLane(l21);
    r2.addLane(l22);
    Road r3 = new Road(new Point(470, 300), new Point(270, 500));
    Lane l31 = new Lane(Lane.Direction.IDENTICAL);
    Lane l32 = new Lane(Lane.Direction.OPPOSITE);
    r3.addLane(l31);
    r3.addLane(l32);
    Road r4 = new Road(new Point(270, 500), new Point(70, 300));
    Lane l41 = new Lane(Lane.Direction.IDENTICAL);
    Lane l42 = new Lane(Lane.Direction.OPPOSITE);
    r4.addLane(l41);
    r4.addLane(l42);

    Junction j1 = new TrafficLightJunction();
    j1.connect(l11, l21);
    j1.connect(l22, l12);
    Junction j2 = new TrafficLightJunction();
    j2.connect(l21, l31);
    j2.connect(l32, l22);
    Junction j3 = new TrafficLightJunction();
    j3.connect(l31, l41);
    j3.connect(l42, l32);
```

```
    Junction j4 = new TrafficLightJunction();
    j4.connect(l41, l11);
    j4.connect(l12, l42);

    map.addRoad(r1);
    map.addRoad(r2);
    map.addRoad(r3);
    map.addRoad(r4);
    map.addJunction(j1);
    map.addJunction(j2);
    map.addJunction(j3);
    map.addJunction(j4);

    Driver tom = new CautiousDriver("Tom");
    Driver jerry = new RecklessDriver("Jerry");

    Vehicle olo = new Car(tom);
    Vehicle olo_v2 = new Car(jerry);

    addVehicle(olo, l11, 1);
    addVehicle(olo_v2, l22, 1);

  }

}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.utils;

/**
 *
 * @author balazs
 */
public class Point {

  public double x, y;

  public Point() {
    x = 0;
    y = 0;
  }

  public Point(double x, double y) {
    this.x = x;
    this.y = y;
  }

  public double getX() {
    return x;
  }

  public void setX(double x) {
    this.x = x;
  }

  public double getY() {
    return y;
  }

  public void setY(double y) {
    this.y = y;
  }

  public Point plus(Point p) {
    return new Point(this.x + p.x, this.y + p.y);
  }

  public Point minus(Point p) {
    return new Point(this.x - p.x, this.y - p.y);
  }

  public Point mult(double k) {
    return new Point(this.x * k, this.y * k);
  }

  public Point div(double k) {
    return new Point(this.x / k, this.y / k);
  }

  public double distanceFromOrigin() {
    Point origin = new Point();
```

```
    return distance(origin);
  }

  public double distance(Point p) {
    double dx = x - p.x;
    double dy = y - p.y;
    double distance = Math.sqrt(dx * dx + dy * dy);
    return distance;
  }

  public boolean inSameQuadrant(Point p) {
    if (getX() > 0 && p.getX() < 0) {
      return false;
    }
    if (getX() < 0 && p.getX() > 0) {
      return false;
    }
    if (getY() > 0 && p.getY() < 0) {
      return false;
    }
    if (getY() < 0 && p.getY() > 0) {
      return false;
    }
    return true;
  }

  public Point rotateVector(double degrees) {
    double X = Math.round(this.x * Math.cos(degrees) - this.y * Math.sin(degrees
));
    double Y = Math.round(this.x * Math.sin(degrees) + this.y * Math.cos(degrees
));
    return new Point(X, Y);
  }

  public double angleVector() {
    if (y == 0) {
      if (x < 0) {
        return Math.PI;
      } else {
        return 0;
      }
    } else if (x < 0) {
      if (y > 0) {
        return Math.atan(this.y / this.x) + Math.PI;
      } else {
        return Math.atan(this.y / this.x) - Math.PI;
      }
    } else {
      return Math.atan(this.y / this.x);
    }
  }

    public double angleVectorDegree() {
    if (y == 0) {
      if (x < 0) {
        return Math.PI*(180/Math.PI);
      } else {
        return 0;
      }
```

```
    } else if (x < 0) {
      if (y > 0) {
        return (Math.atan(this.y / this.x) + Math.PI)*(180/Math.PI);
      } else {
        return (Math.atan(this.y / this.x) − Math.PI)*(180/Math.PI);
      }
    } else {
      return Math.atan(this.y / this.x)*(180/Math.PI);
    }
  }
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.utils;

/**
 *
 * @author balazs
 */
public class Size {

  public double width;
  public double height;

  public Size(double width, double height) {
    this.width = width;
    this.height = height;
  }
}
```

```java
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.vehicles;

import trafficsimulator.core.Driver;
import trafficsimulator.core.Vehicle;
import trafficsimulator.utils.Size;

/**
 *
 * @author snorri
 */
public class Bus extends Vehicle {

  public Bus() {
    this(null);
  }

  public Bus(Driver driver) {
    super(driver);
    topSpeed = 6;
    maxAcceleration = 1;
    maxDeceleration = 3;
    optimalDeceleration = 2;
    size = new Size(20, 10);
  }

  @Override
  public String getType() {
    return "Bus";
  }

}
```

```java
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.vehicles;

import trafficsimulator.core.Vehicle;
import trafficsimulator.utils.Size;
import trafficsimulator.core.Driver;

/**
 *
 * @author snorri
 */
public class Car extends Vehicle {

  public Car() {
    this(null);
  }

  public Car(Driver driver) {
    super(driver);
    topSpeed = 10;
    maxAcceleration = 2;
    maxDeceleration = 4;
    optimalDeceleration = 3;
    size = new Size(14, 8);
  }

  @Override
  public String getType() {
    return "Car";
  }

}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import java.util.List;
import org.junit.After;
import org.junit.AfterClass;
import org.junit.Before;
import org.junit.BeforeClass;
import org.junit.Test;
import static org.junit.Assert.*;
import trafficsimulator.utils.Point;

/**
 *
 * @author snorri
 */
public class JunctionTest {

  private Lane lane1;
  private Lane lane2;

  @Before
  public void setUp() {

    Road r1 = new Road(new Point(20, 20), new Point(500, 20));
    lane1 = new Lane(Lane.Direction.IDENTICAL);
    lane2 = new Lane(Lane.Direction.IDENTICAL);
    r1.addLane(lane1);
    r1.addLane(lane2);
  }

  /**
   * Test whether a lane can connect to itself at a junction. This test is not
   * complete
   */
  @Test
  public void testLanesJunction1() {
    System.out.println("Opposite lanes at a junction");

    Junction junction = new Junction();
    junction.connect(lane1, lane1);

    fail(); // We shouldn't be able to get to this point

  }

}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import org.junit.Test;
import static org.junit.Assert.*;
import trafficsimulator.utils.Point;

/**
 *
 * @author snorri
 */
public class LaneTest {

  private Lane lane1;
  private Lane lane2;
  private Road road;

  public void setUp(Point start, Point end, Lane.Direction dir1, Lane.Direction
dir2) {

    road = new Road(start, end);
    lane1 = new Lane(dir1);
    lane2 = new Lane(dir2);
    road.addLane(lane1);
    road.addLane(lane2);

  }

  /**
   * This test checks if right and left parameters are calculated correctly if a
   * horizontal road is created and its direction is to the right like this: ->
   * with two lanes that are both IDENTICAL.
   */
  @Test
  public void testLanesHorizontalRight() {
    System.out.println("Lanes horizontal right");

    Point startLeft = new Point(100, 100);
    Point endLeft = new Point(400, 100);

    setUp(startLeft, endLeft, Lane.Direction.IDENTICAL, Lane.Direction.IDENTICAL
);
    /*
     System.out.println("lane1LeftStartPointX: " + lane1.getLeftStartPoint().get
X());
     System.out.println("lane1LeftStartPointY: " + lane1.getLeftStartPoint().get
Y());
     System.out.println("lane1LeftEndPointX: " + lane1.getLeftEndPoint().getX())
;
     System.out.println("lane1LeftEndPointY: " + lane1.getLeftEndPoint().getY())
;
     System.out.println("lane1RightStartPointX: " + lane1.getRightStartPoint().g
etX());
     System.out.println("lane1RightStartPointY: " + lane1.getRightStartPoint().g
etY());
```

```
     System.out.println("lane1RightEndPointX: " + lane1.getRightEndPoint().getX(
));
     System.out.println("lane1RightEndPointY: " + lane1.getRightEndPoint().getY(
));
     System.out.println("lane2LeftStartPointX: " + lane2.getLeftStartPoint().get
X());
     System.out.println("lane2LeftStartPointY: " + lane2.getLeftStartPoint().get
Y());
     System.out.println("lane2LeftEndPointX: " + lane2.getLeftEndPoint().getX())
;
     System.out.println("lane2LeftEndPointY: " + lane2.getLeftEndPoint().getY())
;
     System.out.println("lane2RightStartPointX: " + lane2.getRightStartPoint().g
etX());
     System.out.println("lane2RightStartPointY: " + lane2.getRightStartPoint().g
etY());
     System.out.println("lane2RightEndPointX: " + lane2.getRightEndPoint().getX(
));
     System.out.println("lane2RightEndPointY: " + lane2.getRightEndPoint().getY(
));
     */
    double expXLeftStartLane1 = startLeft.getX();
    double expYLeftStartLane1 = startLeft.getY();
    double expXRightStartLane1 = startLeft.getX();
    double expYRightStartLane1 = startLeft.getY() + lane1.laneWidth;
    double expXLeftEndLane1 = endLeft.getX();
    double expYLeftEndLane1 = endLeft.getY();
    double expXRightEndLane1 = endLeft.getX();
    double expYRightEndLane1 = endLeft.getY() + lane1.laneWidth;
    double expXLeftStartLane2 = startLeft.getX();
    double expYLeftStartLane2 = startLeft.getY() + lane1.laneWidth;
    double expXRightStartLane2 = startLeft.getX();
    double expYRightStartLane2 = startLeft.getY() + lane1.laneWidth + lane2.lane
Width;
    double expXLeftEndLane2 = endLeft.getX();
    double expYLeftEndLane2 = endLeft.getY() + lane1.laneWidth;
    double expXRightEndLane2 = endLeft.getX();
    double expYRightEndLane2 = endLeft.getY() + lane1.laneWidth + lane2.laneWidt
h;

    double resultXLeftStartLane1 = lane1.getLeftStartPoint().getX();
    double resultYLeftStartLane1 = lane1.getLeftStartPoint().getY();
    double resultXRightStartLane1 = lane1.getRightStartPoint().getX();
    double resultYRightStartLane1 = lane1.getRightStartPoint().getY();
    double resultXLeftEndLane1 = lane1.getLeftEndPoint().getX();
    double resultYLeftEndLane1 = lane1.getLeftEndPoint().getY();
    double resultXRightEndLane1 = lane1.getRightEndPoint().getX();
    double resultYRightEndLane1 = lane1.getRightEndPoint().getY();
    double resultXLeftStartLane2 = lane2.getLeftStartPoint().getX();
    double resultYLeftStartLane2 = lane2.getLeftStartPoint().getY();
    double resultXRightStartLane2 = lane2.getRightStartPoint().getX();
    double resultYRightStartLane2 = lane2.getRightStartPoint().getY();
    double resultXLeftEndLane2 = lane2.getLeftEndPoint().getX();
    double resultYLeftEndLane2 = lane2.getLeftEndPoint().getY();
    double resultXRightEndLane2 = lane2.getRightEndPoint().getX();
    double resultYRightEndLane2 = lane2.getRightEndPoint().getY();

    assertEquals(expXLeftStartLane1, resultXLeftStartLane1, 2.1);
    assertEquals(expYLeftStartLane1, resultYLeftStartLane1, 2.1);
```

```
    assertEquals(expXRightStartLane1, resultXRightStartLane1, 2.1);
    assertEquals(expYRightStartLane1, resultYRightStartLane1, 2.1);
    assertEquals(expXLeftEndLane1, resultXLeftEndLane1, 2.1);
    assertEquals(expYLeftEndLane1, resultYLeftEndLane1, 2.1);
    assertEquals(expXRightEndLane1, resultXRightEndLane1, 2.1);
    assertEquals(expYRightEndLane1, resultYRightEndLane1, 2.1);

    assertEquals(expXLeftStartLane2, resultXLeftStartLane2, 2.1);
    assertEquals(expYLeftStartLane2, resultYLeftStartLane2, 2.1);
    assertEquals(expXRightStartLane2, resultXRightStartLane2, 2.1);
    assertEquals(expYRightStartLane2, resultYRightStartLane2, 2.1);
    assertEquals(expXLeftEndLane2, resultXLeftEndLane2, 2.1);
    assertEquals(expYLeftEndLane2, resultYLeftEndLane2, 2.1);
    assertEquals(expXRightEndLane2, resultXRightEndLane2, 2.1);
    assertEquals(expYRightEndLane2, resultYRightEndLane2, 2.1);

  }

  /**
   * This test checks if right and left parameters are calculated correctly if a
   * horizontal road is created and its direction is to the right like this: ->
   * with two lanes where one is IDENTICAL and the other OPPOSITE.
   */
  @Test
  public void testLanesHorizontalRight2() {
    System.out.println("Lanes horizontal right");

    Point startLeft = new Point(100, 100);
    Point endLeft = new Point(400, 100);

    setUp(startLeft, endLeft, Lane.Direction.IDENTICAL, Lane.Direction.OPPOSITE)
;
    /*
     System.out.println("lane1LeftStartPointX: " + lane1.getLeftStartPoint().get
X());
     System.out.println("lane1LeftStartPointY: " + lane1.getLeftStartPoint().get
Y());
     System.out.println("lane1LeftEndPointX: " + lane1.getLeftEndPoint().getX())
;
     System.out.println("lane1LeftEndPointY: " + lane1.getLeftEndPoint().getY())
;
     System.out.println("lane1RightStartPointX: " + lane1.getRightStartPoint().g
etX());
     System.out.println("lane1RightStartPointY: " + lane1.getRightStartPoint().g
etY());
     System.out.println("lane1RightEndPointX: " + lane1.getRightEndPoint().getX(
));
     System.out.println("lane1RightEndPointY: " + lane1.getRightEndPoint().getY(
));
     System.out.println("lane2LeftStartPointX: " + lane2.getLeftStartPoint().get
X());
     System.out.println("lane2LeftStartPointY: " + lane2.getLeftStartPoint().get
Y());
     System.out.println("lane2LeftEndPointX: " + lane2.getLeftEndPoint().getX())
;
     System.out.println("lane2LeftEndPointY: " + lane2.getLeftEndPoint().getY())
;
     System.out.println("lane2RightStartPointX: " + lane2.getRightStartPoint().g
etX());
```

```
     System.out.println("lane2RightStartPointY: " + lane2.getRightStartPoint().g
etY());
     System.out.println("lane2RightEndPointX: " + lane2.getRightEndPoint().getX(
));
     System.out.println("lane2RightEndPointY: " + lane2.getRightEndPoint().getY(
));
     */
    double expXLeftStartLane1 = startLeft.getX();
    double expYLeftStartLane1 = startLeft.getY();
    double expXRightStartLane1 = startLeft.getX();
    double expYRightStartLane1 = startLeft.getY() + lane1.laneWidth;
    double expXLeftEndLane1 = endLeft.getX();
    double expYLeftEndLane1 = endLeft.getY();
    double expXRightEndLane1 = endLeft.getX();
    double expYRightEndLane1 = endLeft.getY() + lane1.laneWidth;
    double expXLeftStartLane2 = road.getRightEndPoint().getX();
    double expYLeftStartLane2 = road.getRightEndPoint().getY();
    double expXRightStartLane2 = road.getRightEndPoint().getX();
    double expYRightStartLane2 = road.getRightEndPoint().getY() - 22;
    double expXLeftEndLane2 = road.getRightStartPoint().getX();
    double expYLeftEndLane2 = road.getRightStartPoint().getY();
    double expXRightEndLane2 = road.getRightStartPoint().getX();
    double expYRightEndLane2 = road.getRightStartPoint().getY() - 22;

    double resultXLeftStartLane1 = lane1.getLeftStartPoint().getX();
    double resultYLeftStartLane1 = lane1.getLeftStartPoint().getY();
    double resultXRightStartLane1 = lane1.getRightStartPoint().getX();
    double resultYRightStartLane1 = lane1.getRightStartPoint().getY();
    double resultXLeftEndLane1 = lane1.getLeftEndPoint().getX();
    double resultYLeftEndLane1 = lane1.getLeftEndPoint().getY();
    double resultXRightEndLane1 = lane1.getRightEndPoint().getX();
    double resultYRightEndLane1 = lane1.getRightEndPoint().getY();
    double resultXLeftStartLane2 = lane2.getLeftStartPoint().getX();
    double resultYLeftStartLane2 = lane2.getLeftStartPoint().getY();
    double resultXRightStartLane2 = lane2.getRightStartPoint().getX();
    double resultYRightStartLane2 = lane2.getRightStartPoint().getY();
    double resultXLeftEndLane2 = lane2.getLeftEndPoint().getX();
    double resultYLeftEndLane2 = lane2.getLeftEndPoint().getY();
    double resultXRightEndLane2 = lane2.getRightEndPoint().getX();
    double resultYRightEndLane2 = lane2.getRightEndPoint().getY();

    assertEquals(expXLeftStartLane1, resultXLeftStartLane1, 2.1);
    assertEquals(expYLeftStartLane1, resultYLeftStartLane1, 2.1);
    assertEquals(expXRightStartLane1, resultXRightStartLane1, 2.1);
    assertEquals(expYRightStartLane1, resultYRightStartLane1, 2.1);
    assertEquals(expXLeftEndLane1, resultXLeftEndLane1, 2.1);
    assertEquals(expYLeftEndLane1, resultYLeftEndLane1, 2.1);
    assertEquals(expXRightEndLane1, resultXRightEndLane1, 2.1);
    assertEquals(expYRightEndLane1, resultYRightEndLane1, 2.1);

    assertEquals(expXLeftStartLane2, resultXLeftStartLane2, 2.1);
    assertEquals(expYLeftStartLane2, resultYLeftStartLane2, 2.1);
    assertEquals(expXRightStartLane2, resultXRightStartLane2, 2.1);
    assertEquals(expYRightStartLane2, resultYRightStartLane2, 2.1);
    assertEquals(expXLeftEndLane2, resultXLeftEndLane2, 2.1);
    assertEquals(expYLeftEndLane2, resultYLeftEndLane2, 2.1);
    assertEquals(expXRightEndLane2, resultXRightEndLane2, 2.1);
    assertEquals(expYRightEndLane2, resultYRightEndLane2, 2.1);
```

```
  }
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import org.junit.Test;
import static org.junit.Assert.*;
import trafficsimulator.utils.Point;

/**
 *
 * @author snorri
 */
public class RoadTest {

  private Road road;

  public void setUp(Point start, Point end) {
    road = new Road(start, end);
    Lane lane1 = new Lane(Lane.Direction.IDENTICAL);
    Lane lane2 = new Lane(Lane.Direction.OPPOSITE);
    road.addLane(lane1);
    road.addLane(lane2);
  }

  /**
   * This test checks if right parameters are calculated correctly if a
   * horizontal road is created and its direction is to the right, like this: ->
   * .
   */
  @Test
  public void testRoadHorizontalRight() {
    System.out.println("Road horizontal right");

    setUp(new Point(100, 100), new Point(400, 100));

    double expYStart = road.getLeftStartPoint().getY() + road.calculateWidth();
    double expXStart = road.getLeftStartPoint().getX();
    double expYEnd = road.getLeftEndPoint().getY() + road.calculateWidth();
    double expXEnd = road.getLeftEndPoint().getX();

    double resultYStart = road.getRightStartPoint().getY();
    double resultXStart = road.getRightStartPoint().getX();
    double resultYEnd = road.getRightEndPoint().getY();
    double resultXEnd = road.getRightEndPoint().getX();

    assertEquals(expYStart, resultYStart, 0.001);
    assertEquals(expXStart, resultXStart, 0.001);
    assertEquals(expYEnd, resultYEnd, 0.001);
    assertEquals(expXEnd, resultXEnd, 0.001);

  }

  /**
   * This test checks if right parameters are calculated correctly if a
   * horizontal road is created and its direction is to the left, like this: <-
   * .
```

```
   */
  @Test
  public void testRoadHorizontalLeft() {
    System.out.println("Road horizontal left");

    setUp(new Point(400, 100), new Point(100, 100));

    double expYStart = road.getLeftStartPoint().getY() - road.calculateWidth();
    double expXStart = road.getLeftStartPoint().getX();
    double expYEnd = road.getLeftEndPoint().getY() - road.calculateWidth();
    double expXEnd = road.getLeftEndPoint().getX();

    double resultYStart = road.getRightStartPoint().getY();
    double resultXStart = road.getRightStartPoint().getX();
    double resultYEnd = road.getRightEndPoint().getY();
    double resultXEnd = road.getRightEndPoint().getX();

    assertEquals(expYStart, resultYStart, 0.001);
    assertEquals(expXStart, resultXStart, 0.001);
    assertEquals(expYEnd, resultYEnd, 0.001);
    assertEquals(expXEnd, resultXEnd, 0.001);

  }

  /**
   * This test checks if right parameters are calculated correctly if a vertical
   * road is created and its direction is to the up, like this: ^ | .
   */
  @Test
  public void testRoadVerticalUp() {
    System.out.println("Road vertical up");

    setUp(new Point(100, 400), new Point(100, 100));

    double expYStart = road.getLeftStartPoint().getY();
    double expXStart = road.getLeftStartPoint().getX() + road.calculateWidth();
    double expYEnd = road.getLeftEndPoint().getY();
    double expXEnd = road.getLeftEndPoint().getX() + road.calculateWidth();

    double resultYStart = road.getRightStartPoint().getY();
    double resultXStart = road.getRightStartPoint().getX();
    double resultYEnd = road.getRightEndPoint().getY();
    double resultXEnd = road.getRightEndPoint().getX();

    assertEquals(expYStart, resultYStart, 0.001);
    assertEquals(expXStart, resultXStart, 0.001);
    assertEquals(expYEnd, resultYEnd, 0.001);
    assertEquals(expXEnd, resultXEnd, 0.001);

  }

  /**
   * This test checks if right parameters are calculated correctly if a vertical
   * road is created and its direction is to the right, like this: | v .
   */
  @Test
  public void testRoadVerticalDown() {
    System.out.println("Road vertical down");
```

```
    setUp(new Point(100, 100), new Point(100, 400));

    double expYStart = road.getLeftStartPoint().getY();
    double expXStart = road.getLeftStartPoint().getX() - road.calculateWidth();
    double expYEnd = road.getLeftEndPoint().getY();
    double expXEnd = road.getLeftEndPoint().getX() - road.calculateWidth();

    double resultYStart = road.getRightStartPoint().getY();
    double resultXStart = road.getRightStartPoint().getX();
    double resultYEnd = road.getRightEndPoint().getY();
    double resultXEnd = road.getRightEndPoint().getX();

    assertEquals(expYStart, resultYStart, 0.001);
    assertEquals(expXStart, resultXStart, 0.001);
    assertEquals(expYEnd, resultYEnd, 0.001);
    assertEquals(expXEnd, resultXEnd, 0.001);

  }

  /**
   * This test checks if right parameters are calculated correctly if a road
   * that has a downward slope is created and its direction is to the right,
   * like this: \ v .
   */
  @Test
  public void testRoadDownwardRight() {
    System.out.println("Road downward right");

    setUp(new Point(100, 100), new Point(400, 400));

    double expYStart = road.getLeftStartPoint().getY() + 31;
    double expXStart = road.getLeftStartPoint().getX() - 31;
    double expYEnd = road.getLeftEndPoint().getY() + 31;
    double expXEnd = road.getLeftEndPoint().getX() - 31;

    double resultYStart = road.getRightStartPoint().getY();
    double resultXStart = road.getRightStartPoint().getX();
    double resultYEnd = road.getRightEndPoint().getY();
    double resultXEnd = road.getRightEndPoint().getX();

    assertEquals(expYStart, resultYStart, 0.001);
    assertEquals(expXStart, resultXStart, 0.001);
    assertEquals(expYEnd, resultYEnd, 0.001);
    assertEquals(expXEnd, resultXEnd, 0.001);

  }

  /**
   * This test checks if right parameters are calculated correctly if a road
   * that has a downward slope is created and its direction is to the left, like
   * this: / v .
   */
  @Test
  public void testRoadDownwardLeft() {
    System.out.println("Road downward left");

    setUp(new Point(400, 100), new Point(100, 400));

    double expYStart = road.getLeftStartPoint().getY() - 31;
```

```
    double expXStart = road.getLeftStartPoint().getX() − 31;
    double expYEnd = road.getLeftEndPoint().getY() − 31;
    double expXEnd = road.getLeftEndPoint().getX() − 31;

    double resultYStart = road.getRightStartPoint().getY();
    double resultXStart = road.getRightStartPoint().getX();
    double resultYEnd = road.getRightEndPoint().getY();
    double resultXEnd = road.getRightEndPoint().getX();

    assertEquals(expYStart, resultYStart, 0.001);
    assertEquals(expXStart, resultXStart, 0.001);
    assertEquals(expYEnd, resultYEnd, 0.001);
    assertEquals(expXEnd, resultXEnd, 0.001);

  }

  /**
   * This test checks if right parameters are calculated correctly if a road
   * that has an upward slope is created and its direction is to the right, like
   * this: ^ / .
   */
  @Test
  public void testRoadUpwardRight() {
    System.out.println("Road upward right");

    setUp(new Point(100, 400), new Point(400, 100));

    double expYStart = road.getLeftStartPoint().getY() + 31;
    double expXStart = road.getLeftStartPoint().getX() + 31;
    double expYEnd = road.getLeftEndPoint().getY() + 31;
    double expXEnd = road.getLeftEndPoint().getX() + 31;

    double resultYStart = road.getRightStartPoint().getY();
    double resultXStart = road.getRightStartPoint().getX();
    double resultYEnd = road.getRightEndPoint().getY();
    double resultXEnd = road.getRightEndPoint().getX();

    assertEquals(expYStart, resultYStart, 0.001);
    assertEquals(expXStart, resultXStart, 0.001);
    assertEquals(expYEnd, resultYEnd, 0.001);
    assertEquals(expXEnd, resultXEnd, 0.001);

  }

  /**
   * This test checks if right parameters are calculated correctly if a road
   * that has an upward slope is created and its direction is to the left, like
   * this: ^ \.
   */
  @Test
  public void testRoadUpwardLeft() {
    System.out.println("Road upward left");

    setUp(new Point(400, 400), new Point(100, 100));

    double expYStart = road.getLeftStartPoint().getY() − 31;
    double expXStart = road.getLeftStartPoint().getX() + 31;
    double expYEnd = road.getLeftEndPoint().getY() − 31;
    double expXEnd = road.getLeftEndPoint().getX() + 31;
```

```
    double resultYStart = road.getRightStartPoint().getY();
    double resultXStart = road.getRightStartPoint().getX();
    double resultYEnd = road.getRightEndPoint().getY();
    double resultXEnd = road.getRightEndPoint().getX();

    assertEquals(expYStart, resultYStart, 0.001);
    assertEquals(expXStart, resultXStart, 0.001);
    assertEquals(expYEnd, resultYEnd, 0.001);
    assertEquals(expXEnd, resultXEnd, 0.001);

  }

}
```

```
/*
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 * and open the template in the editor.
 */
package trafficsimulator.core;

import org.junit.runner.RunWith;
import org.junit.runners.Suite;

//JUnit Suite Test
@RunWith(Suite.class)
@Suite.SuiteClasses({
  RoadTest.class,
  VehicleTest.class,
  JunctionTest.class,
  LaneTest.class
})

/**
 *
 * @author snorri
 */
public class TrafficSimulatorTestSuite {
}
```

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates
 * and open the template in the editor.
 */
package trafficsimulator.core;

import org.junit.Test;
import static org.junit.Assert.*;

import trafficsimulator.utils.Point;
import trafficsimulator.utils.Size;
import trafficsimulator.vehicles.*;

/**
 *
 * @author snorri This class will be changing a lot. After the changes more
 * thorough testing will be done.
 */
public class VehicleTest {

  /**
   * Test the height of a reckless car.
   */
  @Test
  public void testHeightRecklessCar() {
    System.out.println("Height of a reckless car");

    Lane lane = new Lane(Lane.Direction.IDENTICAL);
    Vehicle recklessCar = new Car();

    Size expResult = new Size(14, 8);
    Size result = recklessCar.getSize();

    assertEquals(expResult.height, result.height, 0.001);
  }

  /**
   * Test the height of a reckless bus.
   */
  @Test
  public void testHeightRecklessBus() {
    System.out.println("Height of a reckless bus");

    Lane lane = new Lane(Lane.Direction.IDENTICAL);
    Vehicle recklessBus = new Bus();

    Size expResult = new Size(20, 10);
    Size result = recklessBus.getSize();

    assertEquals(expResult.height, result.height, 0.001);
  }

  /**
   * Test if a reckless bus moves
   */
  @Test
  public void testRecklessBusMovement() {
    System.out.println("Movement of a reckless bus");
```

```
    Road road = new Road(new Point(20, 20), new Point(500, 20));
    Lane lane = new Lane(Lane.Direction.IDENTICAL);
    road.addLane(lane);
    Vehicle recklessBus = new Bus();

    double initialPos = recklessBus.getPosition().getX();
    recklessBus.step();
    double finalPos = recklessBus.getPosition().getX();

    assertTrue(finalPos > initialPos);
  }

  /**
   * Test vehicle outside of road boundaries
   */
  @Test
  public void testRecklessBusOutsideRoad1() {
    System.out.println("Creation of vehicle outside of Road parameter");

    Road road = new Road(new Point(20, 20), new Point(500, 20));
    Lane lane = new Lane(Lane.Direction.IDENTICAL);
    road.addLane(lane);
    Vehicle recklessBus = new Bus();

    double roadStartX = road.getLeftStartPoint().getX();
    double roadStartY = road.getLeftStartPoint().getY();
    double roadEndX = road.getLeftEndPoint().getX();
    double roadEndY = road.getLeftEndPoint().getY();
    double recklessBusX = recklessBus.getPosition().getX();
    double recklessBusY = recklessBus.getPosition().getY();

    assertTrue((recklessBusX >= roadStartX && recklessBusX <= roadEndX)
            || (recklessBusY >= roadStartY && recklessBusY <= roadEndY));
  }

  @Test
  public void testRecklessBusOutsideRoad2() {
    System.out.println("Movement of a vehicle outside of road");

    final Road road = new Road(new Point(20, 20), new Point(500, 20));
    final Lane lane = new Lane(Lane.Direction.IDENTICAL);
    road.addLane(lane);
    final Vehicle recklessBus = new Bus();

    Simulation s = new Simulation() {

      @Override
      protected void init() {
        map.addRoad(road);
        addVehicle(recklessBus, lane, 1);
      }
    };

    double roadStartX = road.getLeftStartPoint().getX();
    double roadStartY = road.getLeftStartPoint().getY();
    double roadEndX = road.getLeftEndPoint().getX();
    double roadEndY = road.getLeftEndPoint().getY();
    double recklessBusX = recklessBus.getPosition().getX();
```

```
    double recklessBusY = recklessBus.getPosition().getY();

    assertTrue((recklessBusX >= roadStartX && recklessBusX <= roadEndX)
            || (recklessBusY >= roadStartY && recklessBusY <= roadEndY));
  }
}
```