Final Report

team_we_got_this

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What are our goals? We need to be able to say in two sentence what the goal of building our simulation is?

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Introduction

1 Literature Review

In what follows we will evaluate the different traffic simulations presented in current literature. We will begin by discussing the different categories of traffic simulations and their use in representing different types of road networks. Thereafter we will focus on Microscopic traffic simulations as these best meet the specifications of our system presented in section 2.

1.1 Background

In order to accurately study a real-life system, it is often necessary to first model this system by abstracting some information. Once this model has been made, one can build a simulation to make several observations of the model. Finally one analyses the information collected from the simulation in order to make inferences and suggestions [Sokolowski and Banks, 2011]. A traffic simulation can be classified in several ways - microscopic, mesoscopic and macroscopic. Another distinction of a traffic simulator is discrete or continuous. In a discrete system the variables change at set intervals of time whereas in a continuous system the variables change continuously with time.

Macroscopic traffic simulations are traffic simulations capable of showing the effect of small changes on vast and complex networks. Whereas a microscopic traffic simulation is used to model individual movement of cars in smaller sections of a network. For example one might use a microscopic simulation to observe movement of a vehicle in a specific intersection which has had a large number of accidents in a year. Microscopic models are also more suitable for studying changes such as a new road ramp because they focus on parameters such as velocity and acceleration [Sokolowski and Banks, 2011]. Macroscopic and mesoscopic models are similar in their approaches as they capture traffic dynamics in lesser detail. This results in a faster and easier simulator which is more suitable for larger networks. On the other hand, a microscopic simulator is applied to a smaller area as it better represents vehicle and driver-behaviour [Burghout et al., 2005]. These are attributes we would like to model in our simulation, hence it would seem a microscopic model would best represent our simulation.

1.2 Microscopic Simulations

Before categorising our model, it was necessary to further explore different microscopic simulations to see what other attributes we could include in our simulation. In [Namekawa et al., 2005], the author describes a cell automation method for realizing a microscopic model. In this simulation the main aim is to have vehicles that have the capability to make their own decisions. The road network has physical attributes such as widths, shapes and slopes. They also have logical attributes such as traffic signals and signs. A vehicle is contained within a cell, this is the state at say time t. At the next time step, $t+1$, the vehicle will have to decide its new cell based on the information of neighbouring cells in the previous time step.

This model has many useful characteristics which we would like to implement in our traffic simulation. The first, is that by giving cells physical attributes as well as logical attributes, we could better represent different types of networks using the same simulation. We could use this in our simulation to allow users to build their own road networks and specify these attributes themselves. In doing this, we hope the simulation will have a broader application. The second - the use of cell automation - by recording information on neighbouring cells, cars could be modelled individually and make unique decisions based on their current position but also on any policies we introduce. Cars having decision making capabilities based on their current state would also improve our ability to model more complex road structures such as roundabouts.

Another microscopic simulation that we would like to draw elements from defines a reactive agent and is presented in [Ehlert and Rothkrantz, 2001]. I n this paper the authors focus on intelligent agents so that vehicles can model individual driving behaviours. The paper defines an intelligent agent as capable of sensing its environment and acting accordingly. This model differs from the above model as drivers can now be classed as aggressive if they break the set behaviours defined below. Each agent has seven behaviours which automate its driving on the network. The first, Road-following, keeps the vehicle on the road whilst the second, Intersection/Changing Lanes, ensures the driver adjusts its speed before changing its direction or reaching an intersection. The Traffic Lights behaviour ensures a car stops at a red or yellow traffic light if that traffic light applies to it. Another necessary behaviour implemented to simulate realistic driving is Car-following. This behaviour requires that a vehicle adjust its speed if the car in front is travelling at a slower speed. The behaviour, Switching Lanes, allows a car to change into another lane in order to overtake a slower car. Applying Other Traffic Rules is a behaviour which allows the simulation to model other rules such as maximum speeds and one-way streets such that drivers will exhibit the necessary actions to comply with these rules. Finally, the Collision Detection and Emergency Breaking behaviour alerts the car when it is about to crash into and object. This behaviour takes priority over all other behaviours.

Whilst some of these behaviours are not necessary for our simpler simulation, many are crucial features which will allow our simulation to accurately measure real-life networks. We would like to represent the following behaviours, as described above, in our simulation:

- Road-following
- Traffic Lights

- Car-following
- Switching lane

We have had great success in representing many of these behaviours in a few of the initial simulations we created. This will be explained in detail in section 2.

1.3 Conclusion

We believe a microscopic system will better represent our simulation because it will focus on smaller areas and individual driver capabilities. We have used the different approaches presented in the two microscopic simulations to influence the requirements and implementation of our system. We would like to use the cell automation used in the first simulation to control where our vehicles are at each tick of the clock. In order to model a real urban environment we would like the vehicles in our system to exhibit the following behaviours, Traffic Lights, Car-following, Road-following and Switching Lanes behaviours from the second simulation.

2 Requirements and Design

2.1 Introduction

In this section we will discuss the requirements of our simulation based on the initial requirements laid out in the introductory slides, the Literature we have reviewed and based on the initial models we created. We will categorise the requirements of our simulation into functional and non-functional requirements. Given this new list of requirements we will prioritise them into one of three subcategories — Necessary, Optional and Extra. Finally we will outline a timetable for the start and completion of each requirement.

Software systems Requirement Engineering is an important part of software development life-cycle as it extracts the key requirements necessary to build a software. By having clear criteria, software engineers can easily analyse, implement and evaluate their system [Nuseibeh and Easterbrook, 2000]. There are five key stages of requirement engineering. The first is the elicitation of requirements where the team identifies, reviews and understands the constraints of the system. The second stage is analysing the constraints followed by writing these constraints into a requirement specification of the system. Once the specification is agreed on, the team will begin timetabling the requirements.

2.2 Requirement Elicitation

The following initial requirements come from the *Introductory Lecture Slides:*

Meta-requirements:

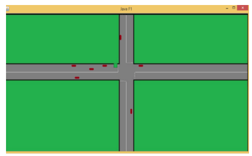
- Development must be coordinated through github repository.

- The source code can be written in any language.
- Documentation must be provided in Latex format and exported as PDF.
- Unit testing of high quality and coverage should be performed.
- Code documentation and comments for methods and variables should be provided.
- Work should be critically evaluated to highlight encountered problems and also parts of the project that worked well.

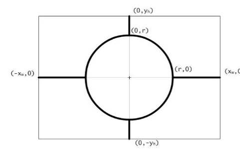
System Requirements:

1. The system must simulate individual vehicles such as cars, coaches and buses.
2. The road network must have different parts including roundabouts and multi-lane junctions.
3. The network must have places where vehicles enter and exit.
4. The model should be able to simulate individual behaviour of drivers, e.g. reckless, cautious and normal.
5. The system should be able to time each car's journey to present efficiency statistics according to purpose and patterns of use.
6. The simulation might support emergency services such as ambulances and give them priority at traffic lights.
7. The model should be able to make use of different policies and test their effectiveness and report on their success or failure rates using a particular measure (e.g. average speed, congestion rate).
8. The engine should have a particular state which depends on how long the simulation has run for and a time granularity constant (macroscopic or microscopic) must be chosen which indicates on how often the state is updated, with vehicles changing their position and new cars being created, old cars being removed.
9. Users should have the ability to configure their own maps of an arbitrary scale.
10. A GUI or command line should be used to visualise maps and simulations.

After considering the available requirements, our team decided to go ahead and implement a number of ideas of how such requirements can be modelled. A description of each system along with an analysis of their benefits and pitfalls are discussed in the next section.



(a) Screen shot of our pixel approach



(b) Using parametric equations to represent a network

2.3 Requirement Analysis

Once we had elicited the requirements we wanted our system to have, we needed to decide how to implement them. As a group there were several viable ideas and so we chose to take some time to explore each option. Each team member had two weeks to explore their idea and at the end of this period they presented to the group. This presentation included whether their option was discrete or continuous, the benefits of their implementation choice and the problems they had with it or they thought would occur. In this section we discuss these initial designs and analyse how each choice of implementation effected our final simulation.

The first option we considered was using a matrix made of hexagons to represent the network. In this way each cell would have row and column coordinates in the matrix to track the position of cars. We hoped that using this method would allow us to check the adjoining cells for cars to prevent collisions. We thought the hexagon-shaped cells would allow us to better simulate a roundabout than square-shaped cells would. In the working simple model using this method, we had achieved working traffic lights. If a light was green for straight ahead only, the cars who wanted to go straight would go while the cars who wanted to turn left would stay stopped at the light. In this simple model we had not yet enabled cars to respond to other cars. Thus if a car was travelling at a faster speed than the car in front of it, it would pass through it. When attempting to implement this as a trial of the model, we decided that a hexagon matrix was an unnecessary complication but there was potential in the use of a matrix to represent the network.

The second option we came up with also used a matrix and was based on the cell automation model [Namekawa et al., 2005]. In this model each cell of a matrix is given attributes and properties. The attributes included the width, height, and type of cell whilst the properties would give information about whether or not the cell is occupied by a vehicle. The most important feature we would include in each cell was information on its neighbouring cells so that cars could make dynamic decisions about where they would go at each tick of the clock in the simulation. Although we had not yet successfully implemented this approach, we did believe it could be used to adequately model the requirements of our system.

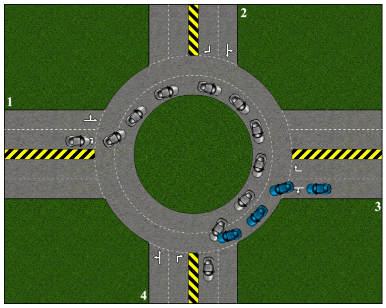
The third option was the first working simulation that the group created. In this simulation, pixels are recoloured every thirty milliseconds to show the movement of cars across the map (see figure 1a). The entry points, exit points, and changing lanes were all dependent on the size of the static map. We had this simulation working very quickly, but we questioned whether it would be dynamic enough to adapt to our growing plans without getting overly complicated. In particular, we were concerned that this approach would hold us back as we tried to develop a multi-lane roundabout where cars would need to know when to change lanes to exit. This model originally had a similar problem with collisions as mentioned in option two where faster cars would pass through slower cars. We were able to implement a level of intelligence in the cars – faster cars could respond to a slower car in front of them by overtaking in the right lane. If, however, the cars were already in the right-hand lane, the car would merely slow down and match the slower speed of the car in front of them while keeping a safe distance. This implementation could model many of the behaviours discussed in [Ehlert and Rothkrantz, 2001], but it would be too reliant on the map and hence it would not be possible to have the user build their own maps.

The final option we considered a continuous model based on a mathematical approach in which our map was represented by several parametric equations dependent on time (see figure 1b). In this way, each car would have its position denoted by a set of coordinates (x, y). The parametric equation used to calculate the car's next position at each time step would be determined using its current position and the intended direction of travel. This solution would simplify the problem of the multi-lane roundabout in the previous approach by merely using two sets of parametric equations for two concentric circles. Although this approach would allow us to accurately calculate where each car is at any given time, it would be difficult to come up with an efficient way to check for nearby vehicles. Again it was clear that the biggest challenge we would face was insuring our cars could respond to other cars in the network.

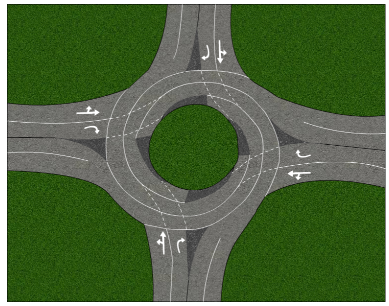
2.3.1 Possible Scenarios and Policies

Another consideration we made when finalising the requirements of our simulation was how we could model real-life scenarios. All of the members of our team had agreed that we wanted one of the options for a user to be a multi-lane roundabout. However, there we foresaw several problems in implementing it.

As our groups focus was on multi-lane roundabouts one of the the problem which exist in real-life which would be a bigger problem in our simulation was how cars exit a multi-lane roundabout. In the figure 2a, we can see that the grey car has approached the roundabout with its final destination being exit 4 and at about the same time a blue car has approached the roundabout with it final destination being exit 1. In this scenario a problem arise because the grey car will need to cut across the path of the blue car in order to exit the roundabout. As a group we discussed how in real-life the driver of the grey car would anticipate this problem and either adjust it's speed so the blue car could proceed before it or the blue car would give way to the grey car. We wanted to model something similar and hence again we needed a way for our cars to



(a) Issue with exiting a multi-lane roundabout



(b) Possible two lane spiral roundabout

have intelligence. Whilst we were considering possible rules for our roundabout, we decide to research problem in existing roundabouts in London. During the research we came across a solution to a dangerous roundabout which was trialled in north London. The roundabout in question had both three and four lane entrances and exits which made it difficult for cars to navigate the roundabout. The solution which was designed (see figure 2b) is a spiral roundabout which insures that the lane the person enters the roundabout in will lead them directly to the correct exit without them having to change lanes on the roundabout. We decided we would also like to model this solution as it is a new a unique solution to a problem which has existed for many years.

2.4 Requirement Specification and Verification

Given the models analysed, we can define new requirements which are more precise than elicited ones. We will begin by categorising them into functional and non-functional requirements. In table 1, we specify the priority of each of the requirements and it is this priority list which will dictate the timetable of the project outlined in section 2.6.

2.4.1 Non-functional Requirements

Reporting: The system should report on the results of a run simulation according to a number of factors: how conjectured the roads were (percentages of road cells occupied by cars to empty road cells) and how long it took cars to get from A to B (in respect to the minimum time it would have taken them without any other cars).

Performance / response time: The simulation should run without lag on a regular University computer (e.g. in MSc lab 534), i.e. 64-bit Inter Core2 Quad CPU @ 2.5GHz for a medium-size simulation. However, when the complexity increases to more than 500x500 cells and 250 cars, the system is allowed to show a reasonable decrease in performance. With 1000x1000 cells and 500 cars, system is not guaranteed to continue responding to user input or show feedback on its state.

Testability: The code for the project must be written by programmers with a fact in mind that it will have to be tested using a unit test framework. For example, when writing in Java, the unit-testing framework would be JUnit. Tests might be written beforehand to promote test-driven development, but it is not compulsory. On the other hand, it is required that every method has a corresponding test code written for it to make sure it works correctly in a variety of situations, such as boundary and corner conditions, therefore edge-cases must be tested.

Usability: It must be easy for users to understand how to use the simulation capabilities. Jakob Nielsen's 10 general principles for interaction design [ref: http://www.nngroup.com/articles/ten-usability-heuristics/] should be considered and applied for implementation of user interface, for example there should be a match between the system and real world so users understand the analogy. This means that cars in the simulation should look like cars and the designs for road and roundabouts must be as realistic as possible. Also, help should be provided for users with explanations of how to use the simulation engine. A heuristic testing for all the 10 principles must be performed in the end of the UIs development life-cycle by an expert.

Portability: The system should be able to run on a computer with JVM installed (thus ensuring that the program can be started on any device which supports Java) or as an applet on a web-page.

Maintainability: The code should make use of interfaces and appropriate design patterns to make sure that all programmers can understand it and make required changes (refactor it) easily.

Extensibility: It should be possible to introduce new features into the system without having to restructure the engines core if additional requirements emerge. For example an appropriate level of abstraction should be used to ensure that a cyclist lane occupied by cyclists, taxis, buses and motorbikes can be incorporated into the system at the later stages of development.

Documentation: Every public method must be documented in the source code in Javadoc-style, including the purpose of the function, description of each parameter and return value, as well as clarification of exceptions using @param, @return, and @throws tags. @author and @version tags must be specified for each class. Documentation of a private method is encouraged when it can help other people working on the project to understand its purpose. Finally, UML diagrams (use-case, class and sequence at least) must be created in the design stage to make sure the principles of the overall model are clearly conveyed to shareholders and the team of developers.

2.4.2 Functional Requirements

Map Designer

1. Users should be able to create a new blank map by specifying its width and height in cells.
2. Users should be capable to click on each cell and choose whether it is empty or a road.
3. If a cell is a road, users should be able to specify in which direction it is going (NORTH, EAST, SOUTH or WEST).
4. If a cell is a road, users should have an option to make it an entry node or an exit node.
5. If a cell is a road, users can place a traffic light on it or remove an existing traffic light from it.
6. A map can be saved to a file with the .map extension which contains binary data of a serialised grid object.
7. Users can load a map saved earlier by choosing a file.
8. Users should be able to erase all objects from the map (i.e. to start over).
9. Map builder should be programmed in ActionScript 3.0. [Screenshot of a blank map, and map with road, cars and traffic lights on it]

Simulator Engine

1. The system must be able to load a map file and initialise the appropriate state of the simulation.
2. The cars must appear from entry nodes according to the flow specified as a parameter.
3. The cars must disappear from exit nodes at every tick of a clock.
4. The simulation controller must move cars according to their speed and direction, making sure that collisions do not occur, e.g. if a car needs to be moved to the next cell which is already occupied by another car, it will not be moved. In the future, a collision can be allowed to occur and cause a traffic jam, but this is subject to changes in requirements.
5. The cars must be allowed to go ahead in their current direction or change direction when they reach a junction.
6. The appropriate methods should exist to make cars enter, follow and exit roundabouts.

7. Traffic light's colour must change according to a certain delay associated with it by the global controller. reconsider this: The possible states are: RED, RED-AMBER, AMBER, GREEN. The exact behaviour of cars in these situations must be specified by a policy.

8. Each car should have a timer which starts when it enters the map and stops when it exits. At this point, statistics are collected on the time taken for it to travel through the road network.

9. The simulation might be paused by the user and its state can be saved by him/her to load later. do we need/have time for this?

10. The vehicles may be able to overtake each other.

11. A behaviour may be added to each vehicle which determines the speed at which they are driving and the decisions they make at traffic lights (e.g. always stop on AMBER for cautious drivers).

12. Special vehicles may be included in the simulation such as ambulances, fire brigades and police services. These special vehicles will get priority at traffic lights and other vehicles will be required to change lanes to give way.

13. A time-granularity constant should be included as a global static variable so that it can be changed easily to test the behaviour of the system and give the user freedom of control.

14. The model should have a GUI implemented in Java Swing with menu items at the top, grid display on the left and buttons for control on the right.

15. The users must be able to specify policies and receive reports when the simulation ends.

2.5 Architectural Patterns

Whenever a team designs a system, there are many different ways to do it and even with clear specifications it can be a challenge to decide which direction is best. Consequently, a software architect can make use of design patterns – the proven good design structures which have emerged from hard-won architectural knowledge [Bass, 2007] – to decide their approach. In our system, we will implement a number of design patterns to make sure we use appropriate tested solutions to save time and help us work well as a team.

2.5.1 Layered Pattern Solution

Complex software systems usually require a clear separation of services so that different modules can be developed and maintained by different team members.

We will use a layered pattern to clearly show which parts make up the whole system and assign modules to each programmer in our group.

The layered pattern divides the software into units called layers [Bass, 2007]. A layer can include a number of modules which together form a cohesive set of services. Layers completely partition a software system and each partition is exposed through a public interface. Furthermore, the ordering is strict, which means that layers above are allowed to use services from layers below but not the other way around, i.e. a unidirectional relations rule must be ensured among the layers. One of the disadvantages of this pattern is that the addition of new layers can add up-front costs and complexity to a system. However, we will design it once (at this stage) since we are not planning to add new layers to our software. Please see figure 3 for a diagram of our layered pattern.

Figure 3: Layered pattern of the simulation

Firstly, the layered pattern diagram is a good way of providing documentation of the essential stack components that our system requires: an OS and appropriate hardware to run a JVM machine [glossary]. Secondly, the data layer is responsible for the handling of data from the real world, e.g. how many cars are coming from different entry points at each point in time. This data could be gathered from cameras installed along the roads or from the mobile apps of drivers who wish to participate in helping to gather statistics about traffic conjectures [NCTA, 2013]. Although it would be very challenging to have our system be able to read information in a similar way, it would be useful to allow users to be able to specify the probability a car will enter a given junction. This will allow the user to correctly model their own networks and design policies to improve problems. Thirdly, the Simulation Model layer uses the provided information about cars currently using the road network and attempts to predict future states of the network. A number of policies will be used in a simulation and one of the aims of this project is to find the most appropriate policy by comparing their performance, thus statistics and policies are two essential sublayers. The Simulation Engine will also move the cars and switch colours on the traffic lights, so control is the third sub-layer. Finally, the state of the model needs to be presented to the user and updated every time a change happens. Therefore, the final layer in our design is the UI layer, which will acquire information from the Simulation Engine layer and render it on the screen (see next section). Development of the GUI can take a long time because it is important for a programmer who is working on the model to see what is going on and to check if his or her code is working correctly (e.g. if a car truly changes lanes). Therefore, a command line output can be used which represents a road network using symbols, such as in the following example where c stands for empty cell, r for road and v for vehicle:

c	*c*	*c*	*c*	*c*
r	*r*	*v*	*r*	*r*
c	*c*	*c*	*c*	*c*
c	*c*	*c*	*c*	*c*

To sum up, the Layered Pattern Solution helps us to clearly define underlying critical components of the system (OS, hardware, JVM) and create a separation of responsibilities by partitioning the system into a number of modules. By drawing different layers, we can see how services depend on each other and what interfaces we need to specify between them. Because the relations between layers is unidirectional, it is clear what parts of the system depend on each other (e.g. UI depends on the Simulation Model which depends on the data, and all three depend on the JVM). Tasks can now be assigned to different programmers who will be working on whichever layer they prefer based on their experience and interest.

2.5.2 Model-View-Controller

The second architecture pattern we will make use of is the MVC module pattern which breaks the system into three components. The three components are the model which represents the application's state and provides interface to application logic, the view which produces a representation of the model to the user and handles user input, and the controller which manages the interaction between the model and the view by translating user actions into changes in the model.

The MVC uses notifies relation to connect instances of model, view and controller, i.e. elements are notified of a state change. The restrictions of this pattern are that at least one instance of each element must be created, and the model component should not interact directly with the controller. Finally, one of the weaknesses of the MVC design pattern is that it may introduce unnecessary complexities for simple programs [Bass, 2007]. In spite of that, our system is not that simple and a number of people will be working on different parts of the simulation engine. Therefore, we decided that we will benefit from the adoption of the MVC: for example, one person will be able to work on the model (logic of moving cars according to a policy) simultaneously with another person programming the UI, such as displaying the map, importing graphics and handling user input.

Our MVC design differs from the design pattern in one way: the controller does not need to change between views because there is only going to be one view (the representation of the map). It is allowed to deviate from the design pattern structures slightly so that it can suit the system's needs and enhance performance.

In every other way, our MVC is the same as in the design pattern: the model is responsible for running the traffic simulation, i.e. updating traffic lights, positioning cars and sending notifications of the updates to the view. Upon receiving the notification, the view queries the model and receives its state in response.

When the user wants to pause (start, stop, or restart) the simulation, he or she clicks on certain buttons in the GUI and the gesture is sent to the controller which translates it into an appropriate message for the model. The model performs necessary transformations (e.g. going back to the initial state in case of a restart) and notifies the view about the update. The overall diagram for the MVC and a sequence diagram for a typical run of a simulation are presented in diagrams 4b and 5.

Problems with UML can three of them be combined on the same page to save space. Explain them here.

2.6 Requirement Management

How can we explain the attributes above if some have already been described in the above functional requirements

Once we defined our functional and non-functional requirements, it was clear that there were a large number of requirements. Although we would like to include every attribute in our system, in order to clearly manage the requirements, we needed to know in what order we should complete them. This would help in creating a schedule for each requirement to be completed so that we could identify which elements were dependent on the completion of another. For example, when building dynamic traffic lights, which would change colour based on the number of cars passing by it, we would first need traffic lights that vehicles would respond to and that would change colour based on a timer. Hence in our specification of the requirement we have given to each attribute a priority:

Necessary - a requirement is prioritised as necessary if it is a core component of the simulation which is deemed to be necessary to achieve our original goals.

Optional - A requirement is categorised as optional if its inclusion would be an important benefit to the overall system but without it we will still achieve our goals.

Extra - A requirement is defined as extra for two reasons. The first is that it is an unnecessary attribute but would build a more realistic simulation. The second reason is that although we might feel the attribute is important it would be too time consuming to build in the given time frame.

Necessary	Optional	Extra
Roads Cars Roundabout Multiple lanes Traffic lights Car timer	Spiral roundabout Emergency vehicles Dynamic traffic lights	Buses Parking Zebra crossing Driver Behaviour Horns/honking

Table 1: Priority listing for the requirement of our system

Add intro to section, explanation of table and Nur's Gantt diagram.

Name	Priority	Start	End	Dependency
1. Road	Necessary			
2. Cars	Necessary			
3. Roundabout	Necessary			1
4. Multiple Lanes	Necessary			1
5. Traffic Lights	Necessary			
6. Car Timer	Necessary			2
7. Spiral Roundabout	Optional			3
8. Emergency Vehicle	Optional			2
9. Dynamic Traffic Lights	Optional			5
10. Buses	Extra			2
11. Parking	Extra			1
12. Zebra Crossings	Extra			1
13. Driver Behaviour	Extra			2
14. Horns/Honking	Extra			13

Table 2: Timetable for the project

3 Implementation

In this section, we describe how we approached the implementation stage of our project. We will start with the waterfall approach to implement the initial "must" requirements from the requirements document. This will be implemented with the help of designs such as Architectural Patterns and UML diagrams from the previous sections. We will make use of the Agile approach if we have time to include optional, non-crucial requirements such as emergency vehicles and behaviour of drivers.

3.1 Project Structure

As defined in the design stage, our project was built around a number of components: (a) data module which simulates appearance of cars, (b) model module which is responsible for controlling the state of a grid, e.g. moving cars and changing colours of traffic lights, (c) UI to display to the user the current state of the road network, and (d) statistics to assess traffic policies. For each of the following, we created a package in our project to separate responsibilities. The outline and short description of each package is presented below. Finally, because we worked as a team of programmers, each person picked a package to work on, which allowed us to focus on one thing at a time and to develop ideas fully. This made sure we had a common vision of the final system which would meet the requirements and deliver the working, tested program on time.

3.1.1 Core Package

The core package comprises the essential classes required for the simulation system to work. They include IGrid interface and Grid implementation, ICell and Cell, ICar and Car, ITrafficLight and TrafficLight, and others (a more detailed description can be found in the documentation section). We use interfaces often to make sure our programming is not bound to concrete implementations but rather to methods provided by an interface. This way a programmer working with IGrid in the View package can safely cooperate with a programmer working with IGrid in the Model package without fearing that at some point in time a method might be refactored to have a different name or do something differently than what is expected from it. Furthermore, the Core package has the Program class which includes the main method to run the application.

Person responsible: Anton.

3.1.2 Model Package

The Model package consists of the Model class, which has a number of methods to control the state of the simulation such as change maps as a response to user input and pause, start and save simulations. Once a grid is loaded, the logic of changing the positions of cars and the colour of traffic lights is defined in the IGridController interface and implemented in the GridController class.

Person responsible: Nur.

3.1.3 View Package

The View package is maintained separately from the Model package to ensure separation of responsibilities and to abstract the business logic from representation as specified in the designs. It uses JFrame to create a window and JPanel to place various components on the stage, for example graphical representation of the map (GridPane), JMenu, logo and statistics graphs. The view depends on resources such as images of cars, empty cells and roads and updates when there is a change in the model.

Person responsible: Zaki.

3.1.4 Statistics Package

TODO

3.1.5 Events Package

Because we are using the layered design pattern, we needed to find a way to pass messages from lower layers to higher layers. In figure 1.2, the structure is as follows: Data Layer –>Model Layer –>UI Layer. A common way to create messages and pass them between classes is by using an Observer pattern, the Events package contains classes and interfaces to do that: DataEvent is the object (body) of an event (e.g. a new car Event will contain coordinates of a new car in its data field), EventDispatchable is an interface which has to be implemented by a class which wants to dispatch messages and EventListener is an abstract class with methods which can be used to listen to messages.

Person responsible: Anton.

3.1.6 Test Package

The Test package includes tests for every method in other packages written in JUnit testing framework. Each member of the team has to write tests for their code as specified in the non-functional requirements specification.

Person responsible: Nur, Zaki, Anton

3.2 Setting Up a Common IDE

Since we are using the version control system, Git, we can maintain the main remote repository in which all the code will go. When people make changes to the code, they commit it to the remote branch on GitHub, and others fetch it to keep an up-to-date version of the system in the local repository. We are also using Eclipse IDE so we can make it update the files in the project folder when a commit with changes is pulled from GitHub to the local computer.

To accomplish this task, one of us creates a new project in Eclipse in the Git folder (Software/Final Model/Java_SimulationEngine). Then each programmer on the team creates a folder on his local computer which will serve as his/her local Git:

mkdir sim

cd sim

Then a team member initialises the Git in this folder and adds a remote origin from the SimulationEngine branch:

git remote add -t SimulationEngine -f origin https://github.com/RochelleA/team_we_got_this.git

Finally, we download all the files which we have in the repo:

git checkout SimulationEngine

After these steps, the sim folder looks like this:
Should we add the pics
Final Sprint - traffic signals, statistics and UI.

3.3 Documentation

export of JavaDoc, plus help for the user how to use the simulation (i.e. to start, click the start button, to finish, click stop button, etc).

3.4 Testing

4 Team Work

In a group project, team work plays a big part in the successes and failures of the project. In this section we discuss what roles each of the group members had and how this helped or hindered the project. We also discuss how the group handled using GitHub to work as a team and what we have learned through this experience.

4.1 Meetings

In the beginning we met twice a week to discuss the project. This was a crucial part of the project and needed every team member. It was here that we faced our first problems as a group. There was a lack of communication which continued to be an issue for the group until the end of the project. At first we struggled to find an instant message application that could be used by all members of the group. For a few weeks we used a combination of both WhatsApp and text messages to communicate, but this caused issues when we would only put the message on the group WhatsApp. This meant that some members of the team would not get the messages and would miss the group meetings. Consequently, we needed a new form of communication and we chose Slack as an alternative which every member of the group was happy to use. However, again we struggled to be consistent with our means of communication and it began to hold the group back. Finally a decision was made that all important messages which needed to be read by all members of the group would be sent by KCL email as this was an application that every member had and would check frequently. Although this worked well for us, it had its drawbacks. The main problem was that it was not as instantaneous as an instant message and we would have to leave at least 24 hours for people to check their emails. Alongside this, Rochelle, as project coordinator would send out a calendar request for all meetings so each member of the team knew when every meeting was. This worked much better as no member of the group missed the team meetings as a result of not knowing they were taking place.

Another way we tried to ensure we were making the best use of our weekly meetings was to set an agenda at the start of every meeting. This allowed every member of the group to bring to attention any issue they were having and also helped us to structure our meetings. At the end of every meeting the project co-ordinator would create a report of the minutes of the meeting. This included the agenda, discussion point – what was discussed in the meeting, and action points – what each member of the team needed to do before the next meeting. These reports were uploaded to GitHub so that every member could look at it if they needed to clarify anything.

Once we were clear of the specifications of the system and we were ready to start designing, we gave everyone the components of the project they were to work on. Then, in the weekly meetings which were decreased to once a week, we would give feedback on what we had done. However it became clear that progress had slowed. It was decided that the waterfall model was not suited to our project and we began to follow the agile scrum method instead. explain this method. Find a space to put the description of waterfall. Perhaps in the implementation section.

4.2 Roles and Subgroups

As a team, we began by discussing what we would all like to gain from the project, where we felt we would be best used and why. This allowed us to delegate roles and tasks based on what would be most advantageous to the team. Whilst these roles were formed at the start of the project, throughout its duration these were adapted to meet the needs as they changed. As a group we tried hard to be as flexible as possible as we realised the demands of others. The main roles of group members are as follows:

Anton - Software engineer and architect

Kim - Graphics coordinator

Nur - Software engineer

Rochelle - Project and documentation co-ordinator

Zaki - Software engineer

4.3 Github

5 Evaluation

6 Peer Assessment

Name	Points
Anton	
Kimberly	
Nur	
Rochelle	
Zaki	

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(a) An example MVC structure from [Bass, 2007]

(b) The MVC design for our simulation

Figure 5: The sequence diagram of an example run of the simulation