Analyse real-world traffic data to understand, model, and predict human driving trajectories

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by

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TO WHOM IT MAY CONCERN

This is to certify that Md Tarique Hussain roll no 2021ITB099, Atif Akhtar roll no 2021ITB103 and Tirthajit Boral roll no 2021ITB105 have done their mini project on "Analyse real-world traffic data to understand, model, and predict human driving trajectories" for the partial fulfilment of the degree of B.Tech. in Information Technology.

During this period, they have completed the project. The report has fulfilled all the requirements as per the regulations of the institute and has reached the standard needed for submission.

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Index

Chapter 1

Introduction

Traffic congestion is a major problem in many cities, leading to wasted time, increased fuel consumption, and increased greenhouse gas emissions. Understanding how people move through the transportation network, identifying traffic hotspots, and developing strategies to optimise traffic flow and reduce congestion are essential to creating safe, sustainable, and efficient transportation systems.

The analysis and modelling of real-world traffic data is an important and challenging task in the field of transportation engineering. Accurate understanding of human driving behaviour and trajectory modelling can help inform the design of more efficient and safer transportation systems. In recent years, the development of advanced sensor technologies, machine learning algorithms, and data analytics tools has enabled the collection and analysis of vast amounts of traffic data from various sources, such as GPS devices, cameras, and sensors embedded in vehicles.

This project aims to analyse real-world traffic data to gain insights into human driving behaviour and develop trajectory models that accurately represent the movements of vehicles in traffic. It uses V2V communication, or vehicle-to-vehicle communication, which allows vehicles to exchange data with one another in real-time, without the need for a centralised server. The project focuses on understanding the factors that influence driving behaviour, such as traffic flow, road geometry, and weather conditions, and how these factors can be modelled to improve traffic flow and safety.

The project contributes to the growing body of research on traffic analysis and trajectory modelling by developing more accurate and efficient models that can inform the design of transportation systems and policies. The findings of this project have the potential to inform the development of intelligent transportation systems that improve traffic flow, reduce congestion and accidents, and enhance the overall efficiency and safety of transportation networks.

Here comes the use of network simulators which considers the vehicles as nodes and enables them to communicate with each other for real time decision making and behaving. During simulation data is processed and an overall decision is been taken for platoons of vehicles through which they behave. To start with modelling, we need to have some geographic location such as city or some specific area, which will be our area where we want dodo some simulation. For this purpose, we will be taking maps from OpenStreetMap, these maps will be then fed into SUMO for modelling and then VEINS framework will be used to make a realistic Vehicular Simulation using mobility from SUMO and Network from OMNeT++.

1.1 V2V Communication

V2V communication, or vehicle-to-vehicle communication, is a technology that enables vehicles to communicate with each other wirelessly without relying on a centralised network. This allows vehicles to exchange information about their position, speed, and other relevant data, which can help improve safety, efficiency, and traffic flow on the road.

V2V communication can be used in conjunction with other technologies, such as RSUs (roadside units) and OBU (on-board units), to analyse real-world traffic data and model human driving trajectories. RSUs are stationary devices that are placed along the road and can communicate with vehicles using V2V or other wireless technologies. They can collect data on traffic flow, speed, and other relevant metrics and transmit that data to a central location for analysis.

OBUs, on the other hand, are devices that are installed in individual vehicles and can communicate with RSUs and other vehicles using V2V technology. They can collect and transmit data on the vehicle's speed, location, and other relevant metrics, which can be used to analyse traffic patterns and model human driving trajectories.

By combining V2V communication with RSUs and OBUs, it is possible to create a detailed picture of real-world traffic data and how drivers behave on the road. This data can then be analysed to identify patterns and trends in driving behaviour, such as common routes, acceleration and braking patterns, and how drivers interact with other vehicles on the road.

This information can be used to develop models that can predict how drivers are likely to behave in different situations, which can help improve road safety and reduce traffic congestion. For example, by analysing data on how drivers react to sudden stops or changes in traffic patterns, it is possible to develop algorithms that can predict how drivers will react to similar situations in the future.

Overall, V2V communication, in conjunction with RSUs and OBUs, has the potential to provide valuable insights into real-world traffic data, which can be used to develop more effective strategies for improving road safety and reducing traffic congestion.

1.2 Simulation of Urban Mobility (SUMO)

SUMO (Simulation of Urban Mobility) is an open-source, microscopic traffic simulator that enables researchers, engineers, and planners to model and analyse the behaviour of individual vehicles on a road network. SUMO is widely used for testing and evaluating advanced transportation systems, such as intelligent transportation systems (ITS), autonomous vehicles, and traffic management strategies.

SUMO is designed to simulate the behaviour of each individual vehicle on a network, taking into account factors such as vehicle dynamics, traffic flow, and road conditions. It can model a wide range of transportation scenarios, from simple intersections to complex urban networks. SUMO also allows users to customise vehicle behaviour and network topology to suit their specific needs.

SUMO's open-source nature makes it a popular choice for researchers and developers in the transportation field. The software is freely available and can be customised to suit specific research needs. SUMO is also designed to integrate with other simulation tools, such as microscopic and macroscopic simulators, allowing users to combine different models and data sources for a more comprehensive analysis.

Overall, SUMO is a powerful and flexible tool for simulating urban traffic flow and evaluating the impact of various interventions on traffic management. It is widely used in research and academia, as well as in industry and government agencies, to inform policy decisions and improve traffic management systems.

1.3 OMNET++

OMNeT++ is a powerful open-source discrete event simulation framework that is widely used in the field of computer networks and distributed systems. It provides a versatile platform for modelling and simulating complex systems, allowing researchers and developers to test and optimize their systems in a controlled environment before deploying them in the real world.

The framework is based on C++ and provides a modular architecture that allows users to create custom modules to implement specific functionality within their simulations. This modularity also makes it easy to add new modules or modify existing ones, allowing users to tailor their simulations to their specific needs.

OMNeT++ supports various communication protocols, traffic patterns, and network topologies, making it a powerful tool for modeling a wide range of communication networks. It also provides a rich set of analysis tools that allow users to visualize and interpret simulation results, including network performance, traffic patterns, and other metrics.

One of the main benefits of using OMNeT++ is that it allows researchers and developers to test their systems in a virtual environment that closely approximates real-world conditions. This can help identify potential issues and improve the performance and reliability of the system before it is deployed.

Overall, OMNeT++ is a powerful and versatile tool for modeling and simulating complex systems in the field of computer networks and distributed systems. Its modular architecture, rich set of modeling and analysis tools, and flexibility make it a popular choice for researchers and developers who need to test and optimize their systems in a controlled environment.

1.4 VEINS Framework

VEINS (Vehicles in Network Simulation) is an open-source framework that allows for the simulation of vehicular communication networks in the OMNeT++ simulation environment. VEINS was developed to enable the evaluation of communication protocols and technologies for vehicular networks, including Dedicated Short-Range Communication (DSRC) and Cellular Vehicle-to-Everything (C-V2X).

VEINS is built on top of SUMO (Simulation of Urban Mobility) and OMNeT++, which allows it to model realistic traffic scenarios and communication networks in a detailed and accurate way. VEINS enables the modeling of various communication technologies and protocols, including wireless access technologies, network layer protocols, and application layer protocols.

VEINS supports the simulation of both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, which allows for the evaluation of various use cases, such as safety applications, traffic management, and infotainment services.

VEINS provides a rich set of pre-built simulation models and tools, which makes it easy for researchers and developers to get started with their simulations. The framework is also highly extensible, allowing users to customize and extend the simulation models and libraries to suit their specific needs.

Overall, VEINS is a powerful tool for simulating and evaluating vehicular communication networks, and is widely used in research and industry to develop and test new communication technologies and protocols for intelligent transportation systems.

Chapter 2

Literature Survey

Traffic analysis and modelling have been the focus of research in transportation engineering for many decades. Traditional traffic analysis methods rely on manual data collection and analysis techniques, such as traffic counts and speed measurements. However, the development of advanced sensor technologies and data analytics tools has enabled the collection and analysis of vast amounts of traffic data from various sources.

The use of machine learning algorithms and data analytics tools for traffic analysis has become increasingly popular in recent years. For example, clustering analysis techniques have been used to identify driving patterns and behaviour based on GPS data (Lu, Cheng, & Lu, 2019). Regression analysis techniques have been used to model the effects of traffic flow, road geometry, and other factors on driving behaviour (Liu & Lu, 2020). Trajectory modelling techniques have been used to develop more accurate and realistic models of vehicle movement in traffic (Luo, Huang, & Lu, 2020).

Several studies have focused on the analysis of human driving behaviour using real-world traffic data. For example, Zhang et al. (2018) used GPS data to analyse the effect of traffic congestion on driving behaviour and found that drivers tend to adjust their speed and acceleration in response to traffic flow. Wang et al. (2021) used data from in-vehicle sensors to analyse the effect of weather conditions on driving behaviour and found that rain and snow significantly impact driver behaviour.

Other studies have focused on developing more accurate and efficient trajectory models for vehicles in traffic. For example, Li et al. (2019) developed a hybrid model that combines a trajectory smoothing algorithm with a support vector regression model to improve the accuracy of trajectory prediction. Ma et al. (2020) proposed a trajectory clustering and fusion method that can accurately represent the complex movements of vehicles in traffic.

Despite the progress made in the field of traffic analysis and modelling, there are still several challenges that need to be addressed. For example, the accuracy and reliability of data collection and processing methods, the need for more comprehensive and integrated data sets, and the challenge of incorporating human factors and psychology into trajectory modelling. The findings of this project have the potential to contribute to the ongoing research efforts in this field by developing more accurate and efficient trajectory models and understanding the factors that influence human driving behaviour.

Chapter 3

Implementation/Design

Step 1: Installation of Software

Before proceeding further, it must be taken into consideration that Linux was used as the preferred operating system in order to minimise system bugs due to linker failure and fasten processing time.

(i) Simulation of Urban Mobility(SUMO): Used for building network scenarios and simulating our project.

(ii) OMNET++ : Used to setup RSUs and have control over the simulation

(iii) Veins Framework : Used for running vehicular network simulation.

Step 2: Generation of Real-World Traffic using OpenStreetMap

SUMO Simulator was used for generating and then extracting the data out of that map. Our research showed that Berlin had such areas where the problem of congestion can be used to suggest solutions for the same.

OpenStreetMap (OSM) is a collaborative project by community and group of researchers to create a free editable map of the world. OpenStreetMap is open data, licensed under the Open Data Commons Open Database License (ODL) by the OpenStreetMap Foundation (OSMF). User can simply visit the open street website and export the specific geographic location, downloaded file would be a .osm.xml file which is accepted by mostly all the simulators available. The downloaded osm file needs to be converted into a .net.xml file to be used by the SUMO simulator. There are two ways of doing this; the simpler one is the three clicks scenario generation. The Python script is available inside the tools folder of the SUMO package, which simply helps in downloading the map from open Street map and converting to SUMO supported format very comfortably and easily.

Syntax for this method is : python/tools/osmWebWizard.py

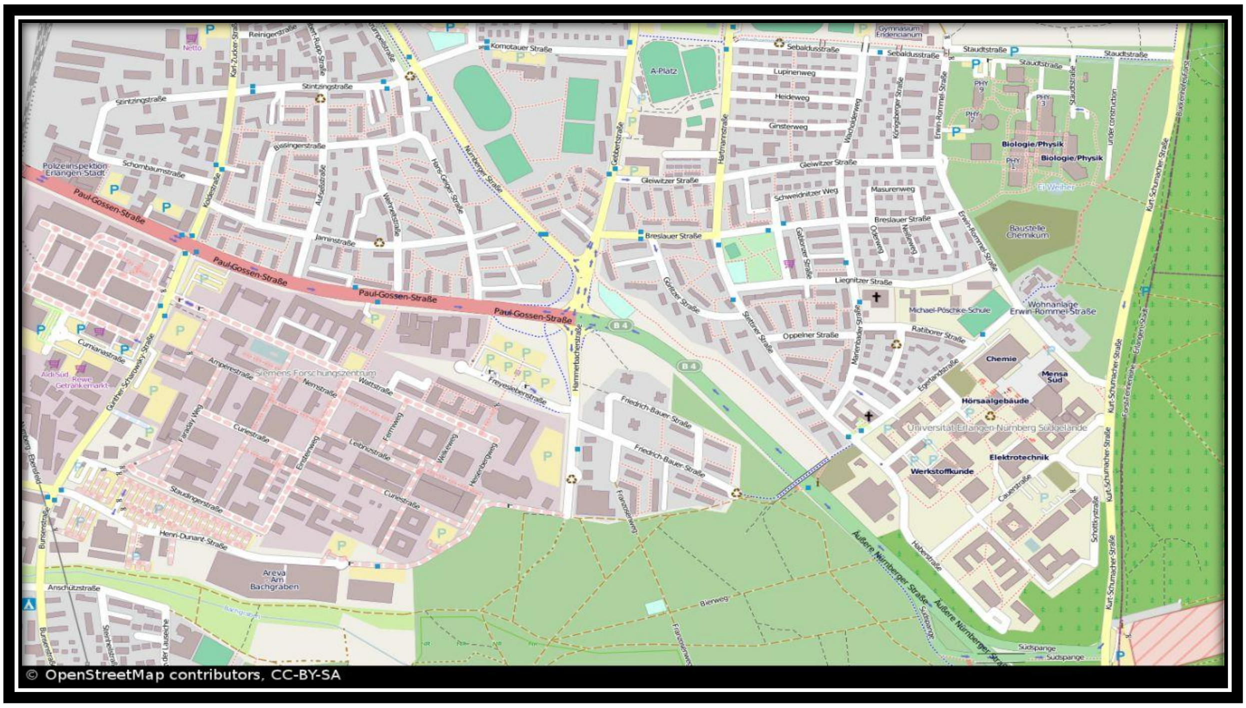

Fig 1:Map of Berlin

The net convert utility is used to convert the osm.xml file to the network file *.net.xml of SUMO.

Syntax is given below : netconvert —osm mymap.osm.xml -o mymap.net.xml.

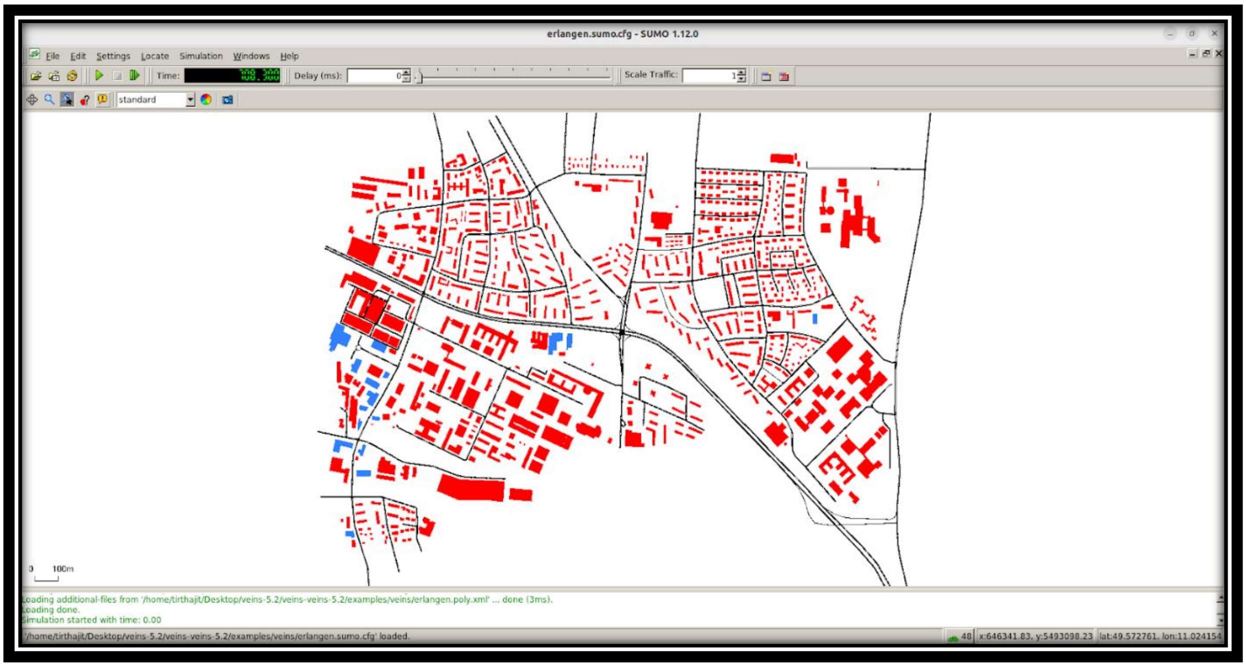

Fig 2: Extracted map in SUMO Simulation

Now the routes of the vehicles were set in such a fashion that it created congestion on the road. Basically the same route was allocated to all the vehicles so that the problem of congestion can be simulated.

We have used the following code to set the route:

```
<routes>

  <vType id="vtype0" accel="2.6" decel="4.5" sigma="0.5" length="2.5" minGap="2.5"
maxSpeed="14" color="1,1,0"/>

  <route id="route0" edges="-39539626 -5445204#2 -5445204#1 113939244#2 -126606716 23339459
30405358#1 85355912 85355911#0 85355911#1 30405356 5931612 30350450#0 30350450#1
30350450#2 4006702#0 4006702#1 4900043 4900041#1"/>

  <flow id="flow0" type="vtype0" route="route0" begin="0" period="3" number="195"/>

</routes>
```

Step 3: Configuring OMNET++

Provide a suitable omnetpp.ini to hold OMNET++ configuration and parameters to our model. A configuration file written in NED language can describe several simulation runs with different parameters.

Step 4:Setting up RSUs.

Road Side Unit (RSU), it is generally described as vehicular communication systems. It is a DSRC (**D**edicated **S**hort **R**ange **C**ommunications) transceiver that is mounted along a road or pedestrian passageway. An RSU may also be mounted on a vehicle or is hand-carried, but it may only operate when the vehicle or hand-carried unit is stationary. Furthermore, an RSU operating under this part is restricted to the location where it is licensed to operate. An RSU broadcasts data to OBUs (**O**n**b**oard **U**nits)or exchanges data with OBUs in its communications zone. An RSU also provides channel assignments and operating instructions to OBUs in its communications zone, when required.

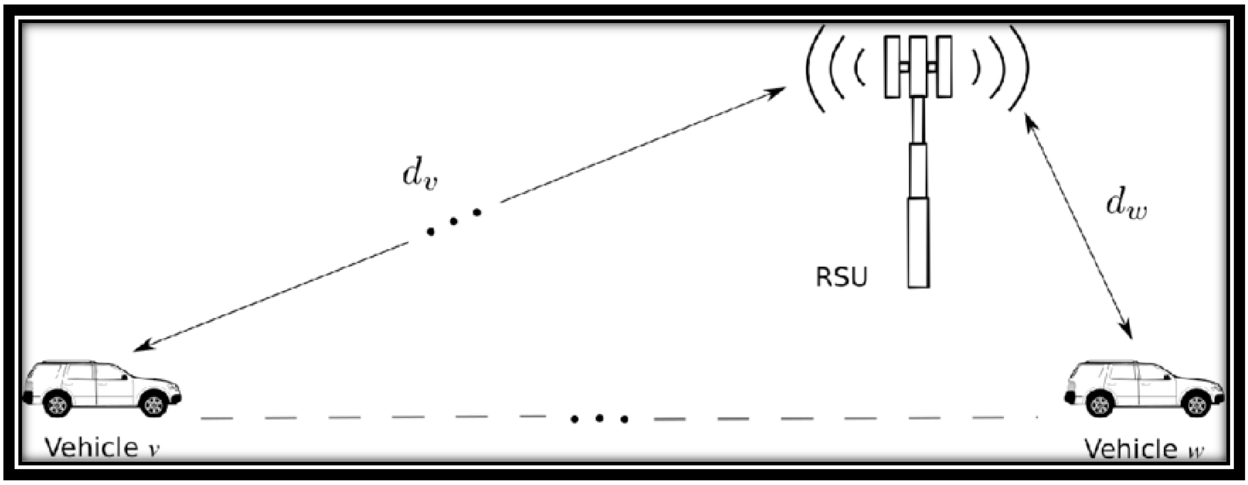

Fig 3:Communication among vehicles through RSU

This project aimed to set up RSUs for inter-vehicle communication using OMNET++.

The following code was used to set the RSU at a position where there is more chances of congestion and an alternate route was available:-

```
*.rsu[0].mobility.x = 2000

*.rsu[0].mobility.y = 2000

*.rsu[0].mobility.z = 3


*.rsu[*].applType = "TraCIDemoRSU11p"

*.rsu[*].appl.headerLength = 80 bit

*.rsu[*].appl.sendBeacons = false

*.rsu[*].appl.dataOnSch = false

*.rsu[*].appl.beaconInterval = 1s

*.rsu[*].appl.beaconUserPriority = 7

*.rsu[*].appl.dataUserPriority = 5

*.rsu[*].nic.phy80211p.antennaOffsetZ = 0 m
```

After setting up RSUs, inter-vehicle communication was simulated at each time instant by using Veins libraries as shown in the code:-

```
import org.car2x.veins.nodes.RSU;

import org.car2x.veins.nodes.Scenario;

network RSUcode extends Scenario

{

  submodules:

    rsu[1]: RSU {

      @display("p=150,140;i=veins/sign/yellowdiamond;is=vs");

    }

}
```

Step 5 : TRACI Connection Establishment

The final step requires the generation of a TRACI server that uses port number 9999 and runs SUMO and Veins Simulation simultaneously.

The following code is written in the NED language to do the same:-

```
*.manager.updateInterval = 1s

*.manager.host = "localhost"

*.manager.port = 9999

*.manager.autoShutdown = true

*.manager.launchConfig = xmldoc("erlangen.launchd.xml")
```

Step 6 : Running the simulation

Before running the final simulation, the following command is written in Omnet++ Shell to start SUMO,Omnet++ and Veins simulation simultaneously:-

```
/home/tirthajit/Desktop/veins-5.2/veins-veins-5.2/sumo-launchd.py -vv -c sumo-gui
Logging to /tmp/sumo-launchd.log
Listening on port 9999
```

The final simulation was then observed and comparisons made.

Chapter 4

Simulation Analysis

As discussed before, the initial simulation aimed to portray the problem of traffic congestion by setting all the vehicles on the same route.

The following figure demonstrates the problem.

Fig 4:Problem of Congestion

The problem is solved by implementing V2V communication. RSUs communicated with vehicles in the vicinity by sending directional messages.

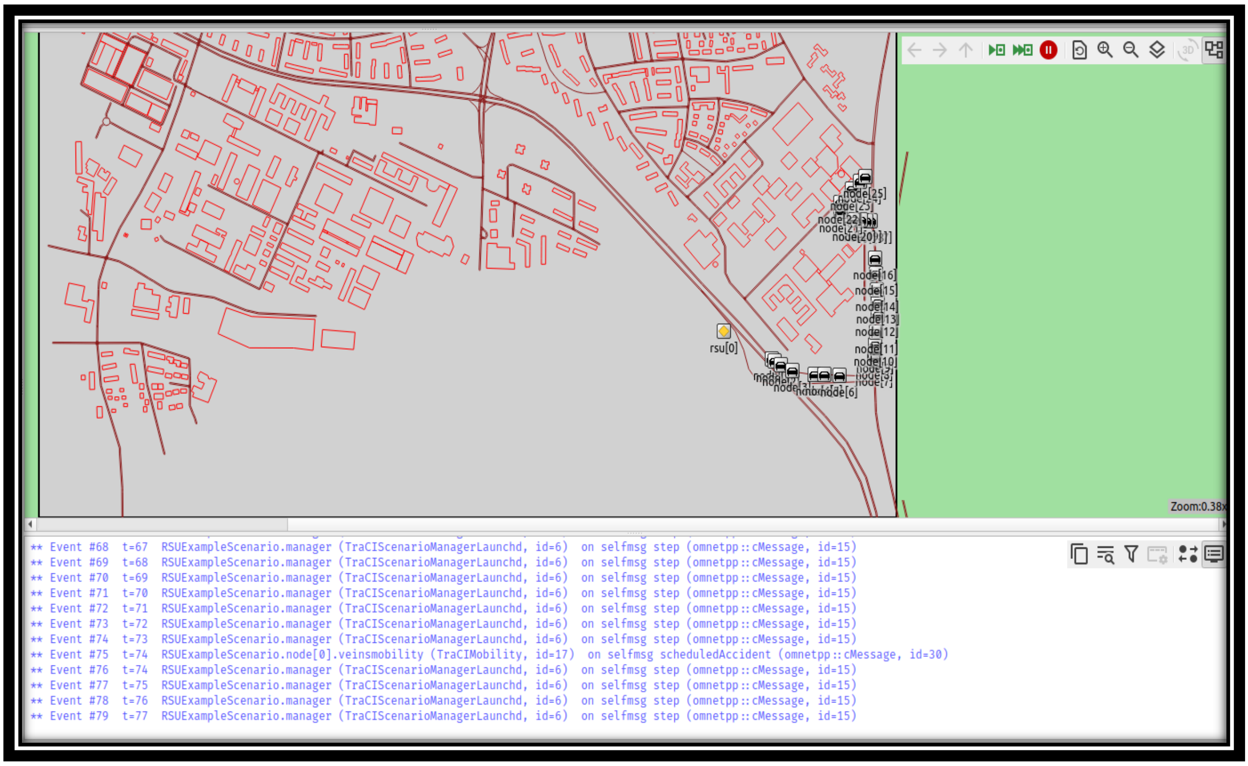

Fig 5: Road Side Unit(RSU)

On receiving the messages, vehicles change their routes and select the best possible route to the destination.

Fig 6: V2V Communication

Now the SUMO simulation is observed where the vehicles are seen taking the least crowded path and reaching their final destination.This solves the problem of congestion to a certain extent.

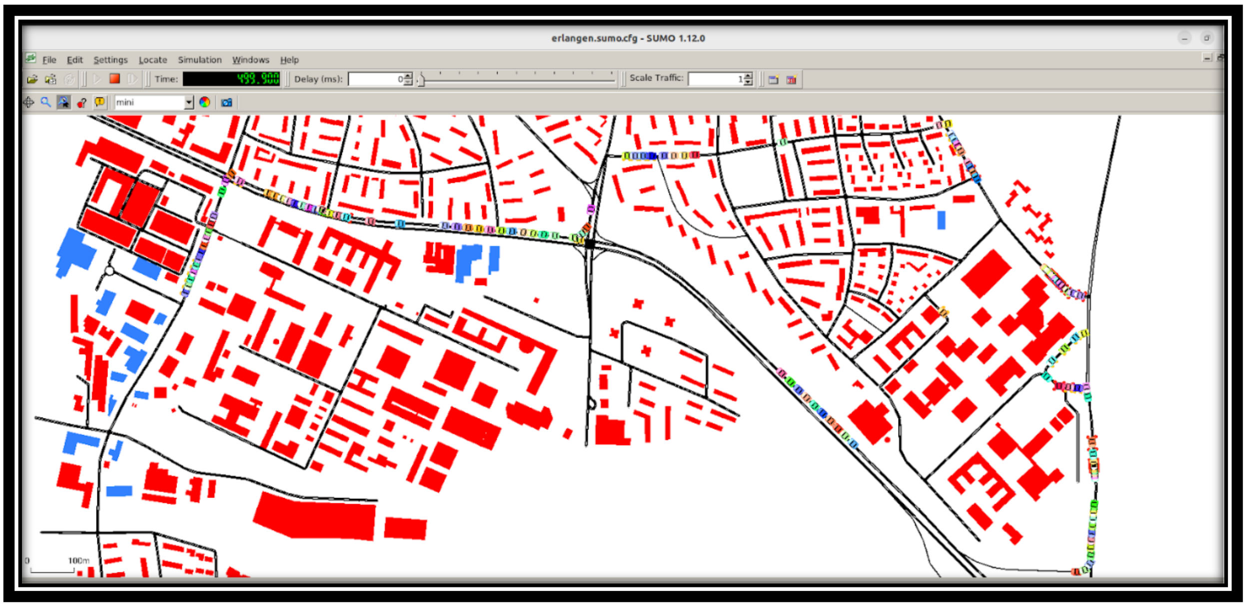

Fig 7: Final SUMO Simulation

Chapter 5

Conclusion

V2V communication, which enables vehicles to communicate with each other, has the potential to significantly reduce traffic congestion and improve traffic flow. When combined with simulation tools such as SUMO, Omnet++, and Veins, it is possible to create a comprehensive simulation environment that can be used to evaluate and test the effectiveness of V2V communication in reducing traffic congestion.

One way V2V communication can help reduce traffic congestion is by providing real-time information about traffic conditions, such as traffic volume and speed, to drivers. This information can be used to optimize traffic flow and reduce the likelihood of congestion. Additionally, V2V communication can be used to coordinate and optimize the behavior of autonomous vehicles, which can help to further reduce congestion and improve traffic flow.

By using simulation tools like SUMO, Omnet++, and Veins, researchers and developers can test and evaluate different scenarios and strategies for implementing V2V communication. This can enable them to determine which strategies are most effective in reducing traffic congestion and improving traffic flow, and can help to guide the development and implementation of V2V communication technologies in the real world.

In conclusion, the combination of V2V communication and simulation tools like SUMO, Omnet++, and Veins has the potential to significantly reduce traffic congestion and improve traffic flow. By developing and evaluating different strategies for implementing V2V communication, researchers and developers can help to guide the development of more efficient and effective traffic management systems.

Future Scope

The findings of this project have the potential to inform the development of intelligent transportation systems that can improve traffic flow and safety. The following are some potential future directions for research in this field:

1. Integration of human factors: While this project aims to develop more accurate trajectory models and understand human driving behavior, there is still a need to incorporate human factors, such as psychology and decision-making, into trajectory modeling. Future research can focus on integrating these factors to develop more realistic models of driving behavior.

2. Real-time traffic analysis: Real-time traffic analysis can help identify traffic congestion and accidents before they occur, allowing for more effective traffic management. Future research can focus on developing real-time traffic analysis tools using machine learning algorithms and data analytics techniques.

4. Multi-modal transportation analysis: While this project focuses on analyzing driving behavior, there is a need to understand how other modes of transportation, such as walking and cycling, interact with vehicular traffic. Future research can focus on developing multi-modal transportation analysis tools that consider the interactions between different modes of transportation.

Overall, the findings of this project have the potential to inform the ongoing research efforts in the field of traffic analysis and trajectory modeling and contribute to the development of more efficient and safer transportation systems.

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