Technische Universität München

Data-Driven Perspectives on Urban Congestion: Integrating Autonomous Vehicle Data and Public Sources for Accurate Estimation.

Master‘s Thesis of Abhishek kotha

Master‘s Thesis – Supervised by Dr.-Ing. Matthias Spangler, M.Sc. Maya Santhira Sekeran,
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Introduction

The main goal of this study is to perform an in-depth analysis of traffic patterns using high-resolution sensor data from AVs on the A995 highway in Munich. The research aims to determine vehicle counts, movement directions, and temporal traffic patterns. This analysis seeks to identify peak periods, average speeds, and flow discrepancies, providing insights into typical traffic behavior and identifying areas of intense congestion.

Unlike traditional fixed-point sensors, AVs can dynamically collect data from various locations. Additionally, the high-resolution sensors on AVs, including LiDAR, radar, and cameras, ensure accurate and real-time traffic data acquisition.

The methodology involves transforming raw sensor data into accessible formats for analysis, ensuring data integrity and accuracy. To capture typical urban traffic dynamics, the study focuses on a specific section of the A995 highway, analyzing traffic over five weekdays. The analysis includes vehicle counts, speed measurements, directional flow, and bounding box calculations to gain a comprehensive understanding of traffic composition and behavior. The objectives include using advanced sensor technologies for data collection, determining vehicle counts and two-direction flow, splitting and counting vehicles over specific segments, analyzing vehicle speeds, and calculating bounding boxes.

Methodology

The study equips an autonomous vehicle with advanced sensors like LiDAR, high-definition cameras, radar, and GPS to capture high-resolution, real-time traffic data along a 4-kilometer stretch of the A995 highway during morning rush hours.

Vehicle detection and tracking are performed using algorithms that cluster LiDAR points into 3D bounding boxes, accurately monitoring vehicle movement. The collected ROS bag data is converted to CSV format and cleaned to ensure accuracy.

Traffic data is processed to compute vehicle counts, speeds, and directions using Python scripts. Vehicles are tracked uniquely for accurate counts, and their travel direction is determined using yaw orientation data. The data is split into 500-meter segments to analyze traffic density, with speeds calculated from velocity components and converted to kilometers per hour. Bounding boxes differentiate vehicle types based on dimensions, aiding in understanding traffic composition.

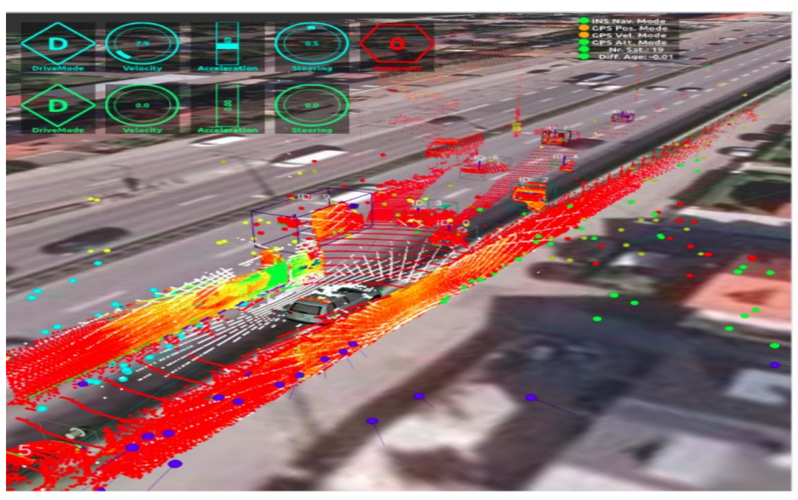

Figure 1:Screenshot of ROS Visualization RViz showing sensor data collected on the A995 highway. The center window displays LiDAR data with 3D bounding boxes around vehicles. Side windows show recorded camera images.

Results and Analysis

Data collection on the A995 highway in Munich was conducted over five weekdays using an autonomous vehicle equipped with LiDAR, radar, cameras, and GPS. The focus was on capturing vehicle positions, velocities, and distances traveled during morning rush hours.

Key Findings:

Highest Traffic Volume: Friday had the highest vehicle count with 949 vehicles, while Wednesday had the lowest with 577 vehicles. Traffic flow towards Munich was generally higher, especially on Thursday and Friday.

Congestion Analysis: Data collection times varied, with Monday and Thursday being the shortest and Friday the longest, indicating increased congestion towards the end of the week.

Speed Patterns: Higher speeds were observed in the negative direction (outbound), indicating less congestion, while lower speeds in the positive direction (towards the city), particularly on Friday, reflected severe congestion.

Vehicle Dimensions: Most vehicles were standard passenger cars, with typical dimensions of around 1.5 meters in width, 3.5 meters in length, and 1.5 meters in height, aiding in understanding traffic composition.

Vehicle count and Two Directional vehicle count Results

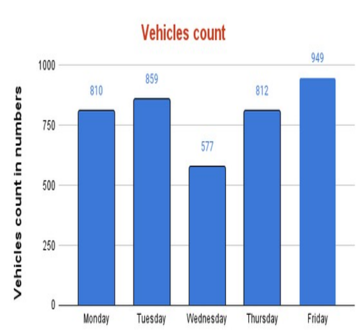

Figure 2:Total vehicle counts from Monday to Friday.

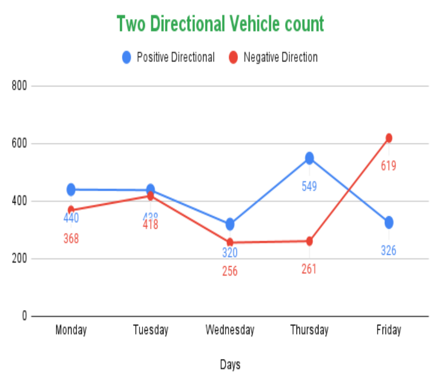

Figure 3:Total number of tracked vehicles for each direction from Monday to Friday.

Positive and Negative Direction Average Speed Results

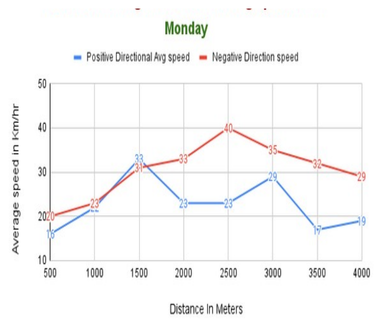

Figure 4: Positive and Negative Direction Average Speed (km/h) on Monday.

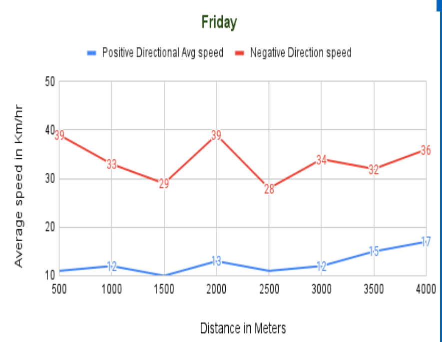

Figure 5: Positive and Negative Direction Average Speed (km/h) on Friday.

Bounding Box Calculation Results

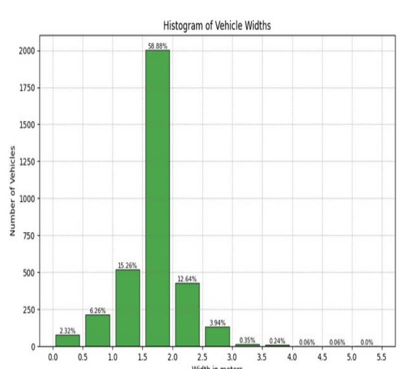

Figure 6: Avg vehicle width distribution on the A995.

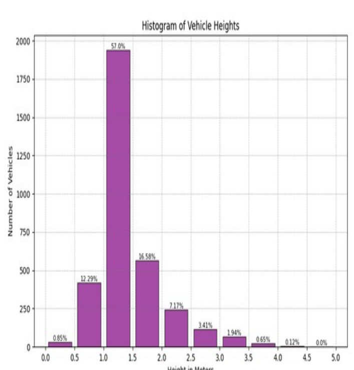

Figure 7: Avg vehicle Height distribution on the A995.

Discussion and Limitations

Discussion:

Our analysis of traffic data on the A995 highway provided valuable insights into traffic patterns and vehicle behavior. We observed peak traffic volumes on Fridays and a mid-week lull on Wednesdays. The two-directional flow analysis highlighted substantial outbound traffic on Fridays. Vehicle dimension analysis confirmed that most vehicles are standard passenger cars, aiding in accurate traffic modeling. Additionally, the variability in vehicle counts along different segments of the highway on Monday and Friday indicates potential congestion points, particularly towards the end of the route on Fridays. These findings underscore the importance of dynamic data collection. Utilizing advanced data analysis techniques can significantly improve the understanding of complex patterns and behaviors.

Limitations:

Sensor Accuracy: Data accuracy depends on the quality of sensors (LiDAR, radar, cameras).

Weather Impact: Sensor performance can be affected by adverse weather conditions.

Data Collection Scope: Limited to five weekdays, not capturing seasonal or special event variations.

Geographical Scope: Focused on a specific section of the A995 highway, limiting generalizability.

Data Processing: Converting raw data from ROS to CSV may introduce errors.

Summary and Outlook

The study successfully integrated autonomous vehicle data for traffic analysis, enhancing our understanding of urban traffic dynamics. The findings underscore the potential of AV data in improving traffic management by identifying peak traffic days, understanding vehicle dimensions, and spotting potential congestion points. Our analysis revealed peak traffic volumes on Fridays and a mid-week lull on Wednesdays. The two-directional flow analysis highlighted substantial outbound traffic on Fridays. Most vehicles were found to be standard passenger cars, aiding in accurate traffic modeling. Additionally, the variability in vehicle counts along different segments of the highway on Monday and Friday indicates potential congestion points, particularly towards the end of the route on Fridays.

Further research should focus on integrating autonomous vehicle data with smart infrastructure to optimize traffic flow in real time and reduce congestion. Utilizing advanced data analysis techniques and machine learning on autonomous vehicle data can improve traffic predictions, allowing for proactive traffic management. This approach can pave the way for more livable and well-functioning urban environments, leveraging autonomous vehicle technology to develop smarter, more efficient, and sustainable transportation systems.

Av – Autonomus Vehicle
ROS - Robot Operating System
LiDAR - Light Detection and Ranging