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Traffic Flow Prediction

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1 Problem statement



Problem Statement

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Traffic Flow Prediction: Urban traffic congestion increases travel times and fuel consumption. Current traffic management approaches are often inadequate for handling complex, dynamic traffic patterns. This project aims to develop a proactive, data-driven traffic management system using probabilistic models to predict traffic flows and congestion patterns.



Research Papers

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- Kim, J., & Wang, G. (2016). Diagnosis and Prediction of Traffic Congestion on Urban Road Networks Using Bayesian Network
- Sun, S., Zhang, C., & Yu, G. (2006). A Bayesian Network Approach to Traffic Flow Forecasting
- Horvat, R., Kos, G., & Ševrović, M. (2015). Traffic Flow Modelling on the Road Network in the Cities
- Adhitama, R. P., & Saputro, D. R. S. (2022). Hill climbing algorithm for Bayesian network structure



Expected outcome

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This project develops a comprehensive approach to traffic analysis and prediction using probabilistic models. The expected outcomes include identifying key congestion causes, generating short-term traffic flow predictions, and analyzing congestion patterns.



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Approach to the problem statement

Data Collection and Aggregation

Traffic parameters such as speed, intensity, travel time, and vehicle are utilized.

Probabilistic Graphical Modeling

This model captures the probabilistic dependencies between factors influencing traffic, such as the time of day, vehicle size, and travel time.

Traffic Forecasting

The model is used to predict traffic intensity at different intervals.

Model Integration

Integrate the trained network into a real-time traffic management system.



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- **Language:** R used for statistical analysis and handling the probabilistic model.
- **Libraries/Frameworks:** bnlearn, readxl for applying probabilistic model and gathering data from databases.
- **Visualization:** Matplotlib for plotting and visualizing data, and prediction results.



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Findings

- Developed Bayesian Network (BN) model for traffic congestion analysis
- Data source: Historical traffic, incident, and weather data from Brisbane
- Model Components:
 - Input: Spatiotemporal factors (time, incidents, weather)
 - Output: Traffic metrics (flow, density, speed)
- Methodology:
 - Manual BN structure based on domain knowledge
 - Validation: Scoring functions and cross-validation
- Analysis techniques:
 - Odds ratios
 - Impact-probability matrices
- Outcome: Data-driven insights into congestion patterns and causes



Use of Bayesian Network in Research

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- Modeling probabilistic dependencies
 - BNs encode joint probability distributions
 - Variables represent factors affecting traffic conditions
- Probabilistic inference
 - BN models support both diagnostic and predictive reasoning
- Scenario analysis
 - Aids traffic managers in anticipating problematic conditions
- Capturing uncertainty
 - Provide probability distributions over predicted traffic states



Methodology

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- Data Collection and Preparation:
 - Historical traffic data from national traffic databases
 - Data aggregation to suitable time intervals
- Analysis and Inference
 - Calculate prior probabilities for various factors
 - Compute posterior probabilities to understand factor influences
 - Use Odds Ratio to identify leading causes of congestion



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Input

The input variables are based on historical traffic data and various factors related to traffic congestion. The input variables include:

- Traffic Speed
- Traffic Intensity
- Travel Time
- Vehicle Categories
- Day of the week
- Time of the day
- Street Network Data



Output

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The outputs of the research project, as presented, include:

- Short-term Traffic Predictions
- Identified Causes of Traffic Congestion
- Bayesian Network Model



EndGoals

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The end goals of the project are:

- Develop a method for predicting traffic congestion using a Bayesian Network model.
- Analyze traffic flow and make short-term predictions
- Create a data-driven framework for better understanding and addressing congestion.
- Improve traffic management by providing accurate and reliable predictions.



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Hill Climbing for Bayesian Networks

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It is used to locate the BN shape by figuring out the conditional independence courting among variables.

- **Input:** Dataset D of traffic flow variables
- **Output:** Optimized Bayesian Network structure Graph



Hill Climbing Algorithm

1 Initialize

- $G = \text{empty graph}$, $\text{score} = \text{BIC}(G, D)$

2 Repeat until no improvement or maximum iterations reached:

- $\text{best_operation} = \text{null}$, $\text{best_score} = \text{score}$
- For each possible operation (add, remove, or reverse an edge) in G :
 - $G_{\text{new}} = \text{Apply operation to } G$
 - If G_{new} is a valid DAG:
 - $\text{new_score} = \text{BIC}(G_{\text{new}}, D)$
 - If $\text{new_score} > \text{best_score}$:
 - $\text{best_operation} = \text{operation}$, $\text{best_score} = \text{new_score}$
- If best_operation is not null:
 - $G = \text{Apply best_operation to } G$
 - $\text{score} = \text{best_score}$

3 Return G as the optimized Bayesian Network structure:

- $\text{LL} = \text{Calculate log-likelihood of } G \text{ given } D$, $k = \text{Number of parameters in } G$, $n = \text{Number of samples in } D$
- Return $\text{LL} - (k * \log(n) / 2)$



Flowchart

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