A New Context-Aware Approach to Traffic Congestion Estimation

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Introduction

- Vehicular traffic estimation is one of the major issues in intelligent transportation systems.

- Current traffic estimation systems rely on infrastructure deployment to monitor traffic state. Therefore, they are costly to implement.

Introduction

- In light of the advances in information technology, the new technology of context-aware computing has emerged as an efficient approach to improve the area of transportation performance.

- using of this key technology for estimating traffic state

Context-Aware Applications

- “A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task.”

- Context-aware applications of the transportation system use the driving context information and provide appropriate operations for the vehicle according to the environment situation.

Proposed Approach

- The proposed context-aware approach estimates traffic state based on fuzzy logic.

- using vehicular contextual information including **average speed** and **mean absolute acceleration**

- The proposed system consists of two phases:
  - ✓ Traffic Information Collection
  - ✓ Fuzzy Traffic Estimation System

Traffic Information Collection

- The proposed system uses the vehicle's average speed context information as the first parameter. A vehicle's average speed is the mean value of its measured instantaneous speeds.

- The **average speed** of a vehicle during a time period T:

$$\overline{V}_T = \frac{v_1 + v_2 + \dots + v_m}{m}$$

Traffic Information Collection

- We use vehicle's mean absolute acceleration (MAA) as the second parameter. MAA is the mean of the absolute value of vehicle's measured accelerations during a certain time period.

- The **mean absolute acceleration** of vehicle during the time period T:

$$MAA_T = \frac{1}{n}\sum_{i=1}^{n} \left|\frac{\Delta v_i}{\Delta t_i}\right|$$

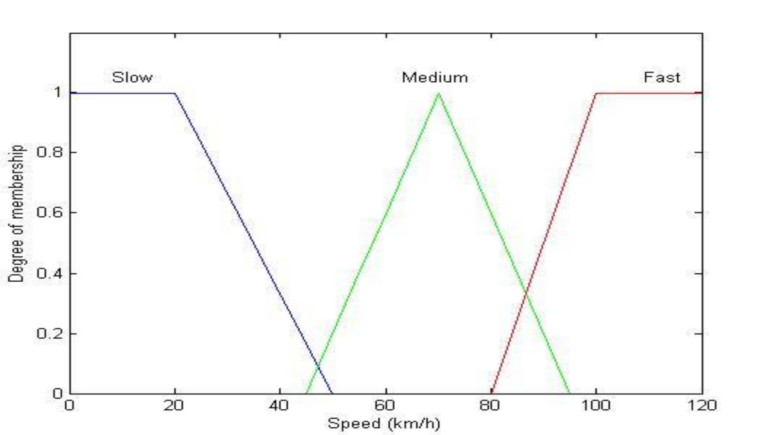
Fuzzy Traffic Estimation System

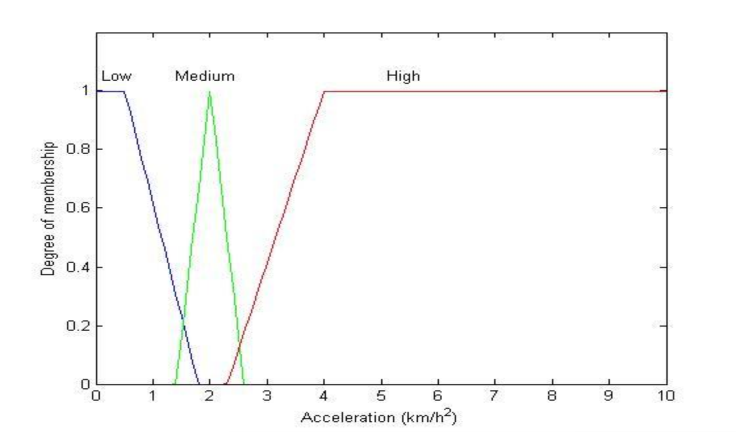
- Contextual information measured by a vehicle, which includes **average speed** and **mean absolute acceleration**, are applied as input variables to the fuzzy system.

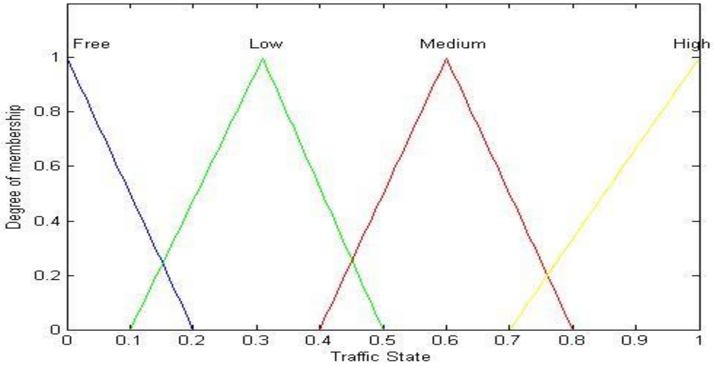
- The fuzzy system aims to measure **the traffic congestion level** as the output variable.

Fuzzy Traffic Estimation System

- The **membership functions** used for input and output variables are defined as follows:







Fuzzy Traffic Estimation System

- **The rule base of the proposed fuzzy system is defined as follows:**

1. If (Speed is Slow) and (Acceleration is Low) then (Traffic is Medium)
2. If (Speed is Slow) and (Acceleration is Medium) then (Traffic is Medium)
3. If (Speed is Slow) and (Acceleration is High) then (Traffic is High)
4. If (Speed is Medium) and (Acceleration is Low) then (Traffic is Low)
5. If (Speed is Medium) and (Acceleration is Medium) then (Traffic is Low)
6. If (Speed is Medium) and (Acceleration is High) then (Traffic is Medium)
7. If (Speed is Fast) and (Acceleration is Low) then (Traffic is Free)
8. If (Speed is Fast) and (Acceleration is Medium) then (Traffic is Free)
9. If (Speed is Fast) and (Acceleration is High) then (Traffic is Low)

Performance Evaluation

- Using of the open source simulator **SUMO** in order to simulate road traffic
- The proposed fuzzy system is evaluated in a highway environment with the following characteristics:
  - ✓ A two-lane highway with a length of 2000 m
  - ✓ maximum speed limit of 120km/h
  - ✓ The flow rate of 1800 vehicles per hour

Performance Evaluation

- **Scenario A:** In this scenario, the maximum speed limit on the highway is set to 120km/h. The vehicles travel in a free flow state.
- **Scenario B:** In this scenario, the speed limit on the highway is 70km/h. There is low traffic congestion in which vehicles travel at a lower speed.
- **Scenario C:** This scenario simulates a high congestion state, i.e., traffic jam, on the highway. This traffic state is made by setting the speed limit to 20km/h.

Simulation results

TABLE1. LEVEL OF TRAFFIC CONGESTION MEASURED BY SAMPLE VEHICLES UNDER SCENARIO A

Vehicles	Average Speed (km/h)	Mean Absolute Acceleration (km/h^2)	Level of congestion
V0	116.44	1.20	0.077
V1	115.32	2.03	0.064
V2	115.55	1.02	0.072
V3	117.31	1.25	0.078
V4	115.34	1.94	0.064
V5	116.47	1.82	0.069
V6	118.16	2.25	0.072
V7	114.34	2.26	0.073
V8	116.68	1.78	0.070
V9	117.12	1.35	0.081

Simulation results

Table2. Level of traffic congestion Measured BY sample vehicles Under Scenario B

Vehicles	Average Speed (km/h)	Mean Absolute Acceleration (km/h^2)	Level of congestion
V0	66.91	1.50	0.301
V1	68.06	0.88	0.303
V2	66.13	1.76	0.303
V3	67.26	1.87	0.303
V4	67.81	2.33	0.315
V5	67.73	1.84	0.303
V6	65.28	2.40	0.350
V7	66.59	2.09	0.303
V8	66.10	0.62	0.303
V9	68.09	2.10	0.303

Simulation results

TABLE3. LEVEL OF TRAFFIC CONGESTION MEASURED BY SAMPLE VEHICLES UNDER SCENARIO C

Vehicles	Average Speed (km/h)	Mean Absolute Acceleration (km/h^2)	Level of congestion
V0	15.13	4.72	0.903
V1	15.21	2.75	0.872
V2	16.91	3.26	0.889
V3	15.80	3.20	0.887
V4	15.20	5.35	0.903
V5	15.72	3.10	0.884
V6	16.61	3.20	0.888
V7	14.54	3.59	0.898
V8	14.17	2.62	0.866
V9	16.11	4.12	0.903

Simulation results

TABLE4. MEAN AND STANDARD DEVIATION OF LEVELS OF TRAFFIC CONGESTION MEASURED IN THREE SCENARIOS

	Scenario A	Scenario B	Scenario C
Mean	0.072	0.3087	0.8893
Standard deviation	0.005617	0.015026	0.012979

CONCLUSION AND FUTURE WORK

- The proposed fuzzy system utilizes the vehicle's average speed and mean absolute acceleration as input variables, and measures traffic congestion level as output.
- The experimental results indicate that simultaneous use of vehicle's speed and acceleration could estimate acceptable and accurate congestion level in different traffic states.

- **FUTURE WORK**
  - Evaluate the performance of the proposed system by more complicated simulation scenarios.
  - Using the mechanism of sharing traffic information between vehicles (vehicle-to-vehicle communications) in order to estimate global roads traffic level.

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