Modeling Traffic Flow on Sloped Road Using A Particle-Based Approach

Poster#: 55

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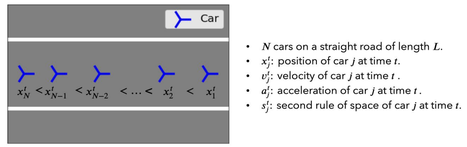
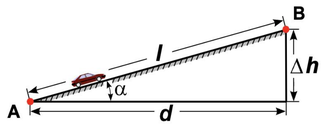
Introduction

- Particle-based models represent cars as individual "particles" that interact and move according to predefined rules.



- N cars on a straight road of length L.
- x_j^t: position of car j at time t.
- v_j^t: velocity of car j at time t.
- a_j^t: acceleration of car j at time t.
- s_j^t: second rule of space of car j at time t.

- Different road grade requires different safety following distance.



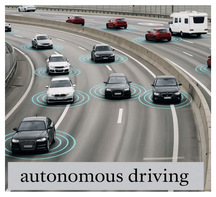
road_grade = Δh / d * 100

- Driving behavior effects seconds rule of space of comfortable driving from front car.

This project enhances traffic modeling by incorporating roa1d grade and diverse driver behaviors using a particle-based approach.

Application

This traffic model can be applied to:



Methodology

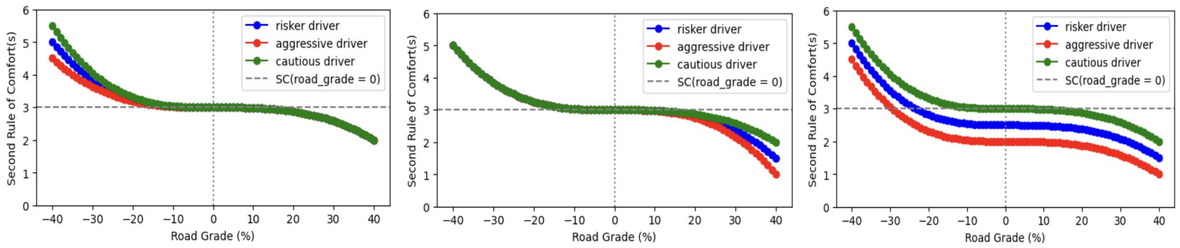
1. Incorporate road grade into to the traffic model through the second rule of comfort (*Sc)* to reflect how incline and decline reflecting driver behaviors.
   - ❏ All kinds of safety distances required by downhill > flat > uphill.
   - ❏ As road grade becomes steeper, the variation in *Sc* becomes more significant.
   - ❏ *Sc* is an indicator of driver type—lower *Sc* value reflect more aggressive driving behavior.
   - ❏ Choose to model Sc using a cubic function of the road grade.

   $Sc(road\_grade) = c \cdot (road\_grade)^3 + Sc(road\_grade = 0)$

Output

road_grade(%)	sc_cautious(s)	change(s)	sc_risker(s)	change(s)	sc_aggressive(s)	change(s)
−40	5.0000000000	–	4.5000000000	–	4.0000000000	–
−39	4.8537187500	−0.14628125	4.3537187500	−0.14628125	3.8537187500	−0.14628125
−38	4.7147500000	−0.13896875	4.2147500000	−0.13896875	3.7147500000	−0.13896875
−37	4.5829062500	−0.13184375	4.0829062500	−0.13184375	3.5829062500	−0.13184375
−36	4.4580000000	−0.12490625	3.9580000000	−0.12490625	3.4580000000	−0.12490625
...	...	...	...	...	...	...
−2	3.0002500000	−0.00059375	2.5002500000	−0.00059375	2.0002500000	−0.00059375
−1	3.0000312500	−0.00021875	2.5000312500	−0.00021875	2.0000312500	−0.00021875
0	3.0000000000	−3.125e−05	2.5000000000	−3.125e−05	2.0000000000	−3.125e−05
1	2.9999921875	−7.8125e−06	2.4999843750	−1.5625e−05	1.9999843750	−1.5625e−05
2	2.9999375000	−5.46875e−05	2.4998750000	−0.000109375	1.9998750000	−0.000109375
...	...	...	...	...	...	...
37	2.6042734375	−0.0312265625	1.7085468750	−0.062453125	1.2085468750	−0.062453125
38	2.5713125000	−0.0329609375	1.6426250000	−0.065921875	1.1426250000	−0.065921875
39	2.5365703125	−0.0347421875	1.5731406250	−0.069484375	1.0731406250	−0.069484375
40	2.5000000000	−0.0365703125	1.5000000000	−0.073140625	1.0000000000	−0.073140625

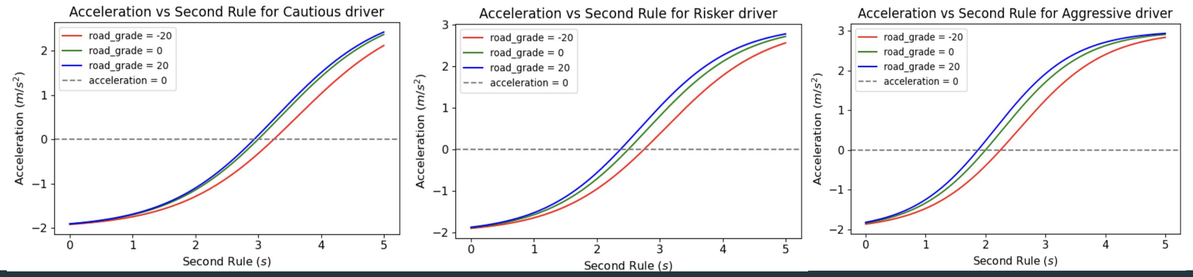
Visualization



2. Apply the second rule of comfort function into the acceleration model that determines a car's acceleration depending on second rule of space $a_j^t(s_j^t)$ which we consider two scenarios:
   - ❏ *alin(s): a* linear function when car is in critical braking state and needs to decelerate significantly.
   - ❏ *anlin(s)* is a generalized logistic function intersecting the x-axis at *Sc,* with a_{min} can be achieved when car has safe following distance.

$$a_j^t(s_j^t) = \begin{cases} a_{lin}(s_j^t) & \text{if } (s_j^t)_{emer} \le s_j^t < (s_j^t)_{min}, \\ a_{nlin}(s_j^t) & \text{if } s_j^t \ge (s_j^t)_{min}. \end{cases}$$

Visualization



Conclusion

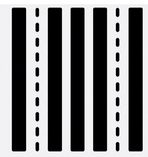
This project advances traditional traffic modeling by incorporating road grade and diverse driver behaviors into a particle-based model. Modeling the second rule of comfort (Sc) as a cubic function of road grade captures variations in following distance across driver types. Integrating Sc into the acceleration model allows dynamic speed adjustments based on safety and comfort, improving realism for traffic simulation on varied terrain.

Future Work

Future efforts on this project will focus on:

construct a richer family of velocity functions

add curvature in addition to slope



extensd to multi-lane setting

Acknowledgement

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Reference

[1] X. WU, S. FU, *Research on Safe Following Distance on an Expressway Based on Braking Process Analysis*. Appl. Sci. 2023.

[2] H. Liu, M. Rodgers, R. Guensler, *Impact of road grade on vehicle speed-acceleration distribution, emissions and dispersion modeling on freeways*. PP 107-122.