Car-following Models, Newell Model

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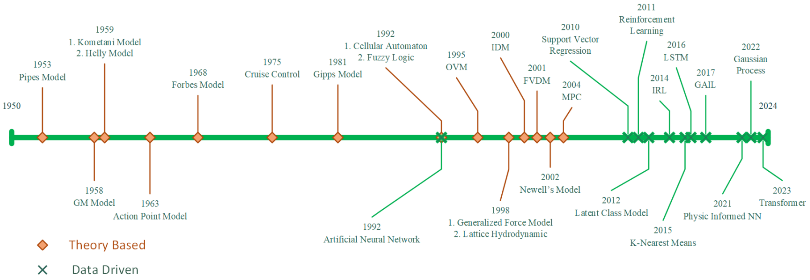
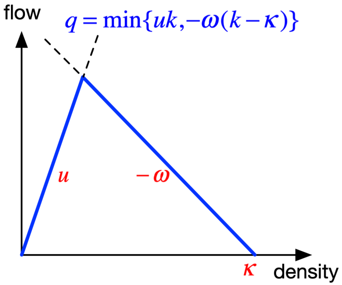
Introduction

- Newell, G. F. (2002). A simplified car-following theory: a lower order model. Transportation Research Part B, 36(3), 195-205.
- The model gives the exact solution of KWT with TFD.
- The model is very simple and is able to reflect the essence of car-following behaviors.



Tianya Zhang, et al., Car-Following Models: A Multidisciplinary Review, arXiv:2304.07143v, 2024

Triangular fundamental diagram



- Only three parameters: u, $-\omega$, and κ
- The only FD to produce kinematic wave solutions where acceleration and deceleration waves travel upstream at a nearly constant speed (because the congestion branch is linear) and without rarefaction fans (because the capacity carries all transition states).

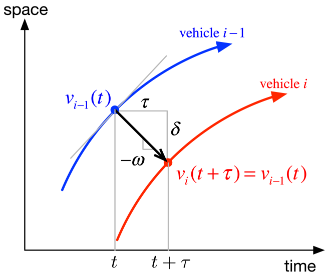
Spacing vs. speed

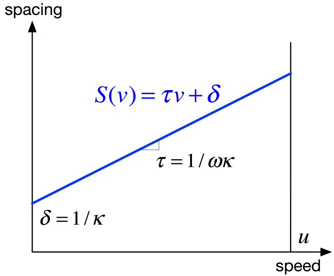
- From the congested branch in the macroscopic level, we can obtain a linear microscopic relationship between spacing and speed for vehicles:

$$S(v) = \tau v + \delta \tag{1}$$

where $\tau = \frac{1}{\omega\kappa}$ is the **wave trip time** between two consecutive trajectories, and $\delta = \frac{1}{\kappa}$ is the **jam spacing**.

- Note: it is in equilibrium states

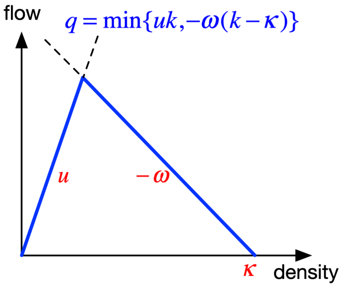




Spacing vs. speed

Deduction: $S(v) = \tau v + \delta$

- Congested branch in TFT: $q_{\text{cong}} = -\omega(k - \kappa)$
- We have $S(v) = \frac{1}{k}$
- Then, we obtain: $S(v) = \frac{1}{\omega\kappa} v + \frac{1}{\kappa} = \tau v + \delta$. How?
- by $q = kv \to q_{\text{cong}}$; get k, and $k \to S(v)$.



Newell model

The Newell model is proposed as follows,

$$x_i(t+\tau) = \min\left\{x_i(t) + u\tau, x_{i-1}(t) - \delta\right\} \tag{2}$$

- where the first term is for free-flow conditions, and the second term is for congested conditions.
- When these terms are equal, it means the traffic is in capacity.

Free-flow conditions

In free-flow conditions, the model is

$$x_i(t+\tau) = x_i(t) + u\tau. \tag{3}$$

It turns out that vehicle i moves with free-flow speed u,
How? distance $=$ speed $\times$ time

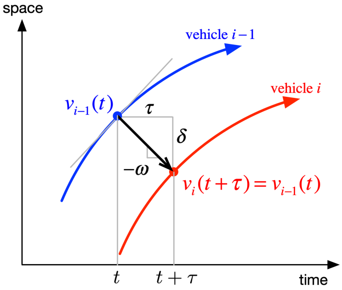
Congested conditions

In congested conditions, the model is

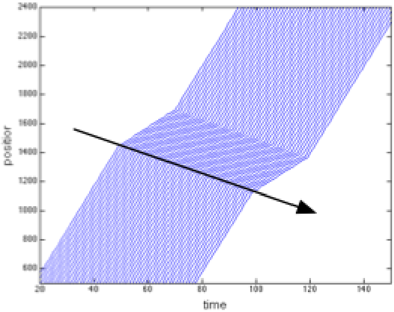
$$x_i(t+\tau) = x_{i-1}(t) - \delta \tag{4}$$

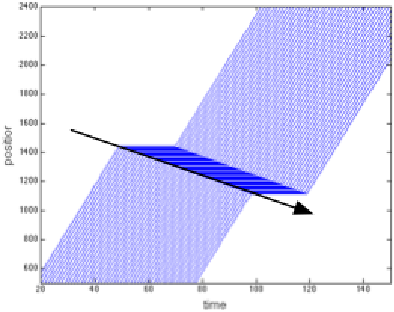
which implies that the trajectory of vehicle i is identical to that of its leader $(i-1)$ but shifted τ forward in time and δ upstream in space.

It turns out shifting vehicle $(i-1)$ along the wave direction $-\omega$, and the spacing $S(v)$.



Examples





Extended reading

- Laval, J. A., Leclercq, L. (2010). A mechanism to describe the formation and propagation of stop-and-go waves in congested freeway traffic. Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences, 368(1928), 4519-41.
- Chen, D., Laval, J., Zheng, Z., Ahn, S. (2012). A behavioral car-following model that captures traffic oscillations. Transportation Research Part B, 46(6), 744-761.

Homework

Comparing the Gipps model and the Newell model coding by using Matlab.

- Plotting the time-space diagrams as shown in the slides of the Gipps model and the Newell model.
    - For the Gipps model, a straight roadway (sudden speed drop) and a ring road (inhomogeneous vehicle distributions in the initial condition);
    - For the Newell model, a straight roadway with different speed drops.
- Trying to use different time steps with Euler and Heun methods.
- Make analyses, not only the influence of the time steps, but also the traffic.

Thank you!