Lane-changing Models, Basic

CIVE.5490, UMass Lowell

Zhengbing He, Ph.D.
https://www.GoTrafficGo.com

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Outline

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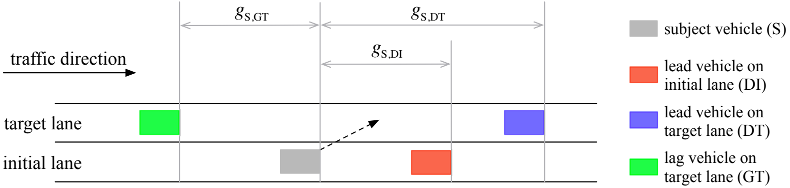
Lane-changing (LC) behaviors

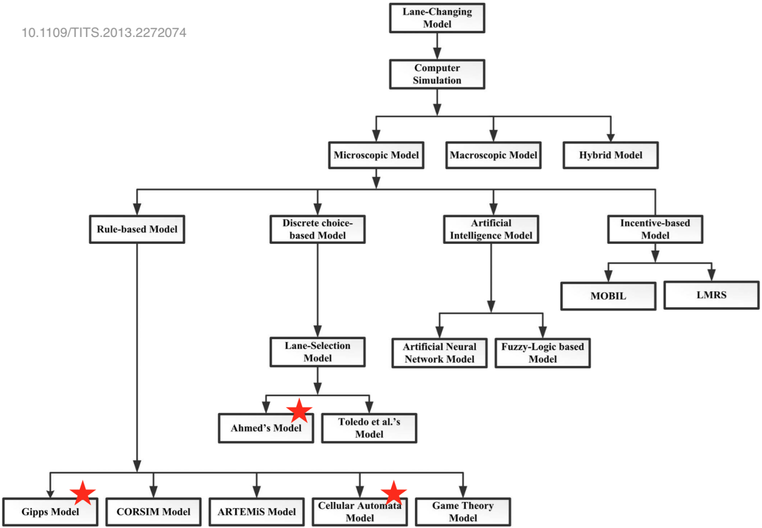
Real traffic is multi-lane traffic. The lane-changing maneuvers are indispensable, which roughly consist of two critical driving behaviors as follows,

- The decision to change lanes:
  - Discretionary: to gain a speed advantage or a better driving environment
  - Mandatory: to reach the planned destination
- LC implementation, such as steering and acceleration, and the impact on surrounding traffic

A typical schematic of the LC process



Classification of the LC models (Since 1980s)



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Analytical Models: Gipps model

P. G. Gipps, A model for the structure of lane-changing decisions, Transportation Research Part B, 20(5): 403-414, 1986.

Analytical Models: Gipps model

- Describes the LC decisions and implementation as the result of three factors: *LC possibility, necessity for changing lanes, LC desirability*
- Includes several factors, such as *the existence of safety gap, locations of permanent obstructions, intent of turning movement, presence of heavy vehicles, and speed advantage*
- Considers several lane-changing reasons: *avoiding permanent obstructions, avoiding dedicated lanes such as transit lanes, turning at downstream intersections, avoiding a heavy vehicle's influence, and gaining speed advantage*

Analytical Models: Gipps model

- A driver's behavior falls into three zones, which are separated by the distance of the driver to the intended turn.
  - When the intended turn is away from her/his position, it has no impact on the driver's latent LC plan
  - When the intended turn is in a zone that is the middle of the way, the driver ignores the speed advantage opportunity
  - When the intended turn is close enough, the driver chooses either the appropriate or adjacent lane, as maintaining or gaining speed is not important

Analytical Models: Gipps model

- The structure of the Gipps LC model is based on his car-following model, which ensures that the follower driver selects his/her speed to bring the vehicle to a safe stop in case of a sudden stop
- In the Gipps LC model, the deceleration of the subject vehicle is used to evaluate the feasibility to change lanes, i.e., if the required deceleration for a LC maneuver is not within the acceptance range, then this LC maneuver is determined as infeasible.
- The subject vehicle driver can alter the braking rate parameter depending on the urgency of the LC maneuver.

Analytical Models: Gipps model

- The Gipps LC model summarizes the LC process as a decision tree with a series of fixed conditions typically encountered on urban arterial, and the final output of this rule-based triggered event is a binary choice (i.e., change/not change).
- Although the Gipps LC model is used in several microscopic traffic simulation tools, it is based upon some tactically simplified assumptions and does not include any framework for model validation based on microscopic driver behavior and traffic data.

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Analytical Models: Ahmed model

K. I. Ahmed, M. E. Ben-Akiva, H. N. Koutsopoulos, and R. G. Mishalani, Models of freeway lane changing and gap acceptance behavior, in Proceeding of 13th International Symposium on Transportation and Traffic Theory, Lyon, France, 24-26, July 1996.

Analytical Models: Ahmed model

- The Ahmed model is a dynamic discrete choice model to capture the heterogeneity in driving characteristics
- The LC decisions are modeled as a three-stage process:
  - Whether or not to make a lane change
  - Target lane choice
  - Acceptance of a gap that is sufficient to execute the lane change

Discrete choice models are used to explain or predict a choice from a set of two or more discrete (i.e. distinct and separable; mutually exclusive) alternatives

Analytical Models: Ahmed model

- Three categories of LC maneuvers:
    - Discretionary LC (DLC)
    - Mandatory LC (MLC)
    - Forced merging (FM): FM occurs when a gap is not sufficient but is created by the driver to execute a LC maneuver in heavily congested traffic conditions.

Ahmed model: Probability of implementing LC

The mathematical formulation of the discrete choice framework is shown in the following functions, which describe the probability that driver n performs MLC, DLC, or FM at time t as follows:

$$P_t(\text{LC}|v_n) = \frac{1}{1 + exp(-X_n^{\text{LC}}(t)\beta^{\text{LC}} - \alpha^{\text{LC}} v_n)} \quad (1)$$

where

- LC= MLC, DLC, FM
- X_n^{LC}: Vector of explanatory variables affecting decision to lane changes;
- β^{LC}: Corresponding vector of parameters;
- v_n: Driver-specific random term;
- α^{LC}: Parameter of v_n .

Ahmed model: Gap acceptance model

A lane change is performed when the available lead and lag gaps in the target lane are greater than their critical gaps. The following equation represents the critical lead and lag gaps for LC maneuvers of driver n at time t:

$$G_n^{\mathrm{cr,gap}j}(t) = \exp(X_n^{\mathrm{cr,gap}j}(t)\beta^{\mathrm{gap}j} + \alpha^{\mathrm{gap}j} v_n + \varepsilon^{\mathrm{gap}j}(t)) \quad (2)$$

where

- gap$j$= lead, lag
- $X_n^{\mathrm{cr,gap}j}(t)$: vector of explanatory variables affecting the critical gap j
- $\beta^{\mathrm{gap}j}$: corresponding vector of parameters
- v_n: Driver-specific random term
- $\alpha^{\mathrm{gap}j}$: Parameter of v_n
- $\varepsilon^{\mathrm{gap}j}(t)$: $N(0, \sigma_{\varepsilon j}^2)$ is a random term

Ahmed model: Gap acceptance model

The probability of accepting a gap during MLC, DLC, or FM for driver n at time t is given as follows:

$$\begin{aligned} & P_n(\text{gap acceptance}|v_n) \\ =& P_n(\text{lead gap acceptable}|v_n)P_n(\text{lag gap acceptable}|v_n) \\ =& P_n(G_n^{\text{lead}}(t) > G_n^{\text{cr,lead}}(t)|v_n)P_n(G_n^{\text{lag}}(t) > G_n^{\text{cr,lag}}(t)|v_n) \end{aligned} \tag{3}$$

where

- $G_n^{\text{lead}}(t)$: probable lead gaps in the target lane
- $G_n^{\text{lag}}(t)$: probable lag gaps in the target lane

Ahmed model: More information

- The model was subsequently implemented in MIcroscopic Traffic SIMulator (MITSIM).
- Although the LC model was unable to capture the trade-offs between MLC and DLC, it accurately described the differences between drivers' MLC, DLC, and FM decisions.

Thank you!