ESTIMATING RISK ATTITUDE AND RISK PERCEPTION IN CAR FOLLOWING

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The aim of this research is to study different car-following situations based on the vehicle type of leader and follower. Established on the Expected Utility Theory, a new car-following model incorporating risk attitude and perception, two important concepts from behavioural economics, is shown.

Both auto and truck drivers are found to be risk averse during the process of car following. This study also finds that the truck driver that follows an auto have a relatively high standard deviation. A high standard deviation means a high probability of making mistakes in risk perception.

This study starts the first step towards explicitly incorporating risk attitude and perception into the car-following model. The proposed model is able to capture the dynamic nature of the car-following behaviour. The speed estimated by the model shows promising results in comparison to the speed observed in real life.

Basic Assumptions

The model is in the context of one vehicle immediately following the other vehicle ahead on a single-lane roadway.

- The period is divided into smaller intervals i = 1, 2 ... etc..
- Each interval is equal in time and defined by drivers’ anticipation time τ.
- At the beginning of an interval, drivers make a choice for the future speed at the end.
- During the interval, both drivers’ acceleration rate and their leaders’ speed are constant.

Utility Functions

Risk attitude describes one’s preference of risks. For analysing risk attitude, constant relative risk aversion (CRRA) is adopted.

- In the case of no collision, the utility is defined by

\[ U_{safe} = \frac{(v_n(t + \tau))^1 - \gamma}{1 - \gamma} \]

\( \gamma \) = driver n’s risk attitude. \( \gamma = 0 \): risk neutrality; \( \gamma > 0 \): risk aversion; \( \gamma < 0 \): risk seeking. When \( \gamma = 1 \), \( U(x) = \ln(x) \).

- The speed with \( v_n(t + \tau) \) = driver n’s future speed at time \( t + \tau \).

- The distility of a rear-end collision is defined over the kinetic energy of driver n.

\[ U_{crash} = -\frac{1}{2} M_n (v_n(t + \tau)^2)^{1 - \gamma} \]

\( M_n \) = gross mass of driver n’s vehicle.

Collision Probability

Risk perception represents the probability of being involved in a rear-end collision perceived by a driver.

- At time \( t \), driver n’s perception of the future spacing between himself and the leader \( n - 1 \) at time \( t + \tau \) follows the normal distribution

\[ f(s_n(t + \tau)) = \frac{1}{\sqrt{2\pi}\sigma} \exp \left[ -\frac{(s_n(t + \tau) - s_{n-1}(t + \tau))^2}{2\sigma^2} \right] \]

\( \sigma \) = standard deviation

\( s_{n-1}(t + \tau) \) = leader n – 1’s length

\( s_n(t + \tau) \) = perceived spacing by driver n

\( s_n(t + \tau) \) = real spacing

- A collision at time \( t + \tau \) would occur in driver n’s perception if

\[ s_n(t + \tau) < l_{n-1} \]

\( l_{n-1} \) = leader n – 1’s length

- The random variable \( s_n(t + \tau) \) is transformed in terms of the standard normal distribution by setting

\[ s_n(t + \tau) = s_n(t + \tau) + Z\sigma \]

\( Z \) = random variable of the standard normal distribution (mean 0, variance 1)

- The perceived probability of a collision at time \( t + \tau \) is

\[ P[s_n(t + \tau) < l_{n-1}] = P \left[ Z < \frac{l_{n-1} - s_n(t + \tau)}{\sigma} \right] = \Phi \left[ \frac{l_{n-1} - s_n(t + \tau)}{\sigma} \right] \]

\( \Phi(Z) \) = cumulative distribution function of standard normal distribution

Proposed Model

Expected Utility Theory provides the theoretical basis.

- The expected-utility function for a certain speed \( v_n(t + \tau) \) is

\[ EU(v_n(t + \tau)) = (1 - P[s_n(t + \tau) < l_{n-1}])U_{safe} + P[s_n(t + \tau) < l_{n-1}]U_{crash} \]

- As necessary conditions of maximization, \( EU'(v_n(t + \tau)) = 0 \) and \( EU''(v_n(t + \tau)) < 0 \). By setting \( EU'(v_n(t + \tau)) = 0 \), the car-following model is proposed as follows

\[ s_n(t + \tau) = l_{n-1} + \frac{(v_n(t + \tau) + v_{n-1}(t))\tau}{2} - v_{n-1}(t)\tau \]

\[ + \sigma \sqrt{2\ln \left[ \frac{4\pi \sqrt{2\pi} (1 - \gamma)}{M_n\tau(v_n(t + \tau))^2} \right]} \]

Calibration & Validation

- Risk attitude and standard deviation of risk perception in different situations of car following are calibrated by nonlinear regression using Next Generation Simulation (NGSIM) data.

- The model is able to fairly accurately estimate the average speed with a high R² value of 0.9504.