CIVIL-557
Project - Modelling

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Objective

Understanding of implementation, estimation, and interpretation of regression-based models within a car-following framework

- Two datasets: I80_data1.txt and US101_data1.txt
- The data have very similar structure and variables to the data that we used during the classes

If some variables are still unclear, please contact me!

The project is in total 50 points.

Task 1 (5 points)

– Using the I80_data1.txt, estimate a GM car-following model for reaction time 0, 1, 2, and 3 seconds.

Implement the model with acceleration-deceleration asymmetry using the specification:

$$\alpha_n(t) = \alpha^g \frac{V_n(t)^{\beta^g}}{\Delta X_n(t)^{\gamma^g}} |\Delta V_n(t - \tau_n)|^{\lambda^g}$$

where g can be acceleration and deceleration regime.

– Which of these models best fits the data? Justify your answer. **(4 points)**

– What do your results imply about the reaction time patterns? **(1 point)**

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Task 2 (10 points)

Pick the model that best fits the data in Task 1. For this model then:

– Discuss the sign, magnitude, and significance of parameters. To what range do the explanatory variables affect the dependent variable and in which way? Discuss what the interpretation of parameters means in practice.

Tip: Numbers may be difficult to interpret in non-linear models. Some plots could help.

Task 3 (10 points)

– Use the US101_data1.txt and estimate the GM model for reaction time 1s. **(5 points)**

– Discuss the sign, magnitude, and significance of parameters. To what range do the explanatory variables affect the dependent variable and in which way? Discuss what the interpretation of parameters means in practice. **(5 points)**

Task 4 (5 points)

– Data I80_data1.txt and US101_data1.txt were collected at two different locations (Location 1 and Location 2 respectively).

– A researcher, has the results of the model estimated using the US101_data1.txt data (Location 2). They assume that these results accurately reflect car-following behaviour at Location 1 too and hence they are of the opinion that there is no need for a model estimation using the data of Location 1 (Data I80_data1.txt). Evaluate the suitability of model results of Location 2 to Location 1. Do you agree with the opinion of the researcher?

Task 5 (5 points)

Except for the GM model there are also other car-following models. For example, Helly's model is expressed as:

$$\alpha_n(t) = \alpha_1 \Delta V_n(t - \tau_n) + \alpha_2 [\Delta X_n(t - \tau_n) - \overline{\Delta X}_n(t)]$$

$$\overline{\Delta X}_n(t) = \beta_1 + \beta_2 V_n(t - \tau)$$

where

- $\alpha_n(t)$ is acceleration of individual n at time t
- $V_n(t)$ is speed of individual n at time t
- $\Delta X_n(t - \tau)$ is the space headway of individual n with the lead vehicle at time $t - \tau$ where τ is the reaction time
- $\Delta V_n(t - \tau)$ is the relative speed of individual n with the lead vehicle at time $t - \tau$
- $\overline{\Delta X}_n(t)$ is the desired space headway
- $\alpha_1, \alpha_2, \beta_1$ and β_2 are parameters to be estimated

Task 5 (5 points)

– Use the I80_data1.txt data and estimate Helly's model for reaction time 1s. **(2 points)**

Tips:

– Helly's model does not assume acceleration-deceleration assymetry. We do not need two different density functions.

– The "lagged" space headway can be calculated as the difference between the lagged positions of the lead and subject vehicles.

Task 5 (5 points)

– Discuss the sign, magnitude, and significance of parameters for Helly's model. To what range do the explanatory variables affect the dependent variable and in which way? Discuss what the interpretation of parameters means in practice. **(2 points)**

– Conceptually, Helly's model assumes a desired space headway as a function of lagged speed and two parameters. Do you see any issues with the specification of the desired headway in terms of using the model for forecasting? If yes, suggest a potential solution. **(1 point)**

Task 6 (15 points)

We have discussed the latent class car-following model. The specification that we used however has an issue; it allows negative acceleration values to be considered in the estimation of the do-nothing density function in the acceleration state and vice versa. Let's see a different version of this model to correct the problem, using the I80_data1.txt data.

The model assumes an acceleration, deceleration, and do-nothing state.

The utility of each state is given as:

$V_{nt}^{acc} = \beta_0^{acc} + \beta_k^{acc} X_{kt}$ (X_{kt} is a generic way to represent independent variables)

$V_{nt}^{dec} = \beta_0^{dec} + \beta_k^{dec} X_{kt}$

$V_{nt}^{dn} = 0$

Task 6 (15 points)

The probability of each state is:

$$P_n(A) = \frac{e^{V_{nt}^{acc}}}{e^{V_{nt}^{acc}} + e^{V_{nt}^{dec}} + e^{V_{nt}^{dn}}}$$

$$P_n(D) = \frac{e^{V_{nt}^{dec}}}{e^{V_{nt}^{acc}} + e^{V_{nt}^{dec}} + e^{V_{nt}^{dn}}}$$

$$P_n(DN) = \frac{e^{V_{nt}^{dn}}}{e^{V_{nt}^{acc}} + e^{V_{nt}^{dec}} + e^{V_{nt}^{dn}}}$$

Task 6 (15 points) - acceleration and deceleration distributions

– Truncated normal distribution for acceleration:

$$\phi(x^{acc})^* = \frac{\frac{1}{\sigma^{acc}}\phi\left(\frac{x^{acc}-\mu^{acc}}{\sigma^{acc}}\right)}{1-\Phi\left(\frac{-\mu^{acc}}{\sigma^{acc}}\right)}$$

– Truncated normal distribution for deceleration:

$$\phi(x^{dec})^* = \frac{\frac{1}{\sigma^{dec}}\phi\left(\frac{x^{dec}-\mu^{dec}}{\sigma^{dec}}\right)}{\Phi\left(\frac{-\mu^{dec}}{\sigma^{dec}}\right)}$$

where: μ^{acc} and μ^{dec} are replaced by the specification of the car-following model (e.g. *sensitivity x stimulus*)

Task 6 (15 points) - do nothing acceleration distribution

– Truncated normal distribution for do-nothing acceleration:

$$\phi(x^{dn}/+)^* = \frac{\frac{1}{\sigma^{dn}}\phi\left(\frac{x^{dn}-\mu^{dn}}{\sigma^{dn}}\right)}{1-\Phi\left(\frac{-\mu^{dn}}{\sigma^{dn}}\right)}, x^{dn} \geq 0$$

– Truncated normal distribution for do-nothing deceleration:

$$\phi(x^{dn}/-)^* = \frac{\frac{1}{\sigma^{dn}}\phi\left(\frac{x^{dn}-\mu^{dn}}{\sigma^{dn}}\right)}{\Phi\left(\frac{-\mu^{dn}}{\sigma^{dn}}\right)}, x^{dn} < 0$$

μ^{dn} and σ^{dn} are parameters to be estimated.

Task 6 (15 points) - other probabilities

– Probability to observe acceleration in the do-nothing state:

$$P(+/DN) = \left[1 - \Phi\left(\frac{-\mu^{dn}}{\sigma^{dn}}\right)\right]$$

– Probability to observe deceleration in the do-nothing state:

$$P(-/DN) = \left[\Phi\left(\frac{-\mu^{dn}}{\sigma^{dn}}\right)\right]$$

where $\Phi()$ is the CDF of a standard normal distribution.

μ^{dn} and σ^{dn} are the same parameters we specified in the previous slide.

Task 6 (15 points) - acceleration/deceleration total probabilities

– Acceleration total probability:

$$f_{nt}^{+} = \phi(x^{acc})^{*}\frac{P_n(A)}{P_n(A)+P(+/DN)P_n(DN)} + \phi(x^{dn}/+)^{*}\frac{P(+/DN)P_n(DN)}{P_n(A)+P(+/DN)P_n(DN)}$$

– Deceleration total probability:

$$f_{nt}^{-} = \phi(x^{dec})^{*}\frac{P_n(D)}{P_n(D)+P(-/DN)P_n(DN)} + \phi(x^{dn}/-)^{*}\frac{P(-/DN)P_n(DN)}{P_n(D)+P(-/DN)P_n(DN)}$$

– Total probability:

$$f^{total} = f_{nt}^{+}(Acceleration \geq 0) + f_{nt}^{-}(Acceleration < 0)$$

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Task 6 (15 points) - acceleration/deceleration density specifications

– For the acceleration and deceleration models a specification similar to the GM model is used

– A difference to the original GM model is that we must specify a condition for considering only positive (and zero) relative speed for acceleration and only negative relative speed for deceleration (as in the solution of the latent class car-following model)

– We must force the signs of the acceleration and deceleration constants to be positive and negative respectively (as in the solution of the latent class car-following model)

– For the GM model, consider a lag of 1s only for relative speed only (no relative speed effect on any other variable)

Task 6 (15 points) - utility specifications

– Estimate a model using relative speed (with lag of 1 s) as the only explanatory variable in acceleration and deceleration utilities

– For the acceleration utility, consider only positive relative speed and for deceleration utility only negative relative speed (as in the solution of the latent class car-following model)

– Then add lagged distance between vehicles as explanatory variables in the utility

Tip: This model has a complex specification and it is difficult to estimate. Once you estimate the model with relative speed as explanatory variable in the utility function, use the results as starting values and estimate again by adding distance between vehicles (lead-follower position)

Task 6 (15 points) - Questions (3 points each)

– Does adding distance significantly improve model fit? Justify your answer.

– Discuss the sign, magnitude, and significance of parameters. To what range do the explanatory variables affect the dependent variable and in which way? Discuss what the interpretation of parameters means in practice.

– Compare the impact of explanatory variables in the acceleration and deceleration with the GM model estimated in Task 1 (for reaction time 1s)

– How do probabilities (of acceleration, deceleration, and do-nothing state) change as a function of the independent variables? Provide a short description.

– Would you recommend the latent class model over the GM model? Which Goodness-of-fit metrics are the most suitable for this comparison and why?

Deliverables and details

– Please provide your codes and results (output files) organised per task.

– Prepare a short report with your responses to the tasks. Keep your answers brief but concise.

– The answers to all tasks can be obtained by using the code solutions of the labs (either directly of with some minor modifications).

Submission Deadline (email at evangelos.paschalidis@epfl.ch): 23:59 on June 23rd 2024 (Sunday)

Suggested reading

Ahmed, K. I. (1999). Modeling drivers' acceleration and lane changing behavior (Doctoral dissertation, Massachusetts Institute of Technology).[Chapter 3]

Koutsopoulos, H. N., Farah, H. (2012). Latent class model for car following behavior. Transportation research part B: methodological, 46(5), 563-578.

Paschalidis, E., Choudhury, C. F., Hess, S. (2021). From driving simulator experiments to field-traffic application: improving the transferability of car-following models. Journal of transportation engineering, Part A: Systems, 147(1), 04020145.