Modelling the Driving Speed on Expressway Ramps

TRANSPORT RESEARCH CENTRE

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ABSTRACT

The question whether there are any causal factors affecting the speed of vehicles in road traffic is of great interest. Identifying such causal effects encounters some difficulties, due to wide range of aspects affecting vehicle drivers, e.g. road traffic volume, road curvature and cross-section characteristics, type of vehicle, road type, weather condition, etc. In this particular case, the speed profiles are treated as functions of distance and therefore it is convenient to employ the functional analysis (FDA) techniques. The main interest lies in finding patterns in driving behaviour on the expressway ramps. This can be reached by finding relation between speed profile and other influential aspects.

DATA

The example data set was collected from GPS on-board units of floating car fleet on expressway ramp in the city of Brno, Czech Republic for half a year. It contains approximately 400 unique drives. The vehicle speed data were recorded every 0.25 seconds, representing a nearly continuous phenomenon. Data were preprocessed before usage of FDA techniques. Drives crossed expressway ramp from direct or merging lane.

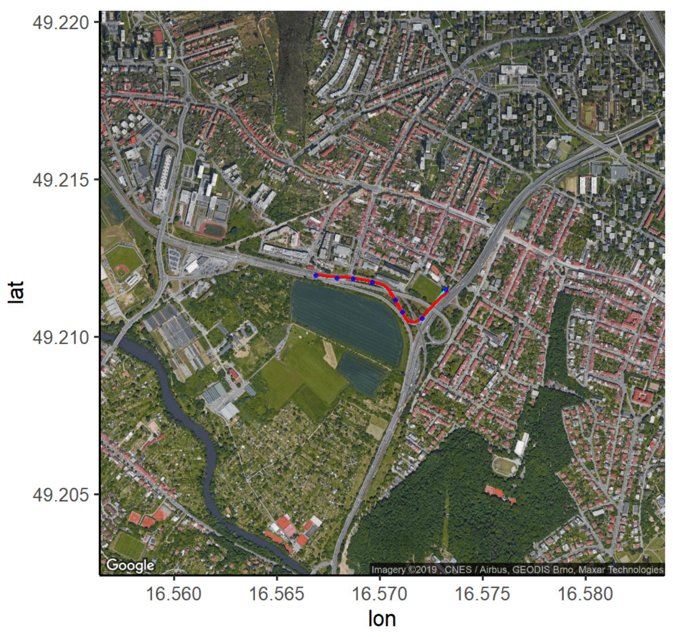

Fig. 1: Location of drives.

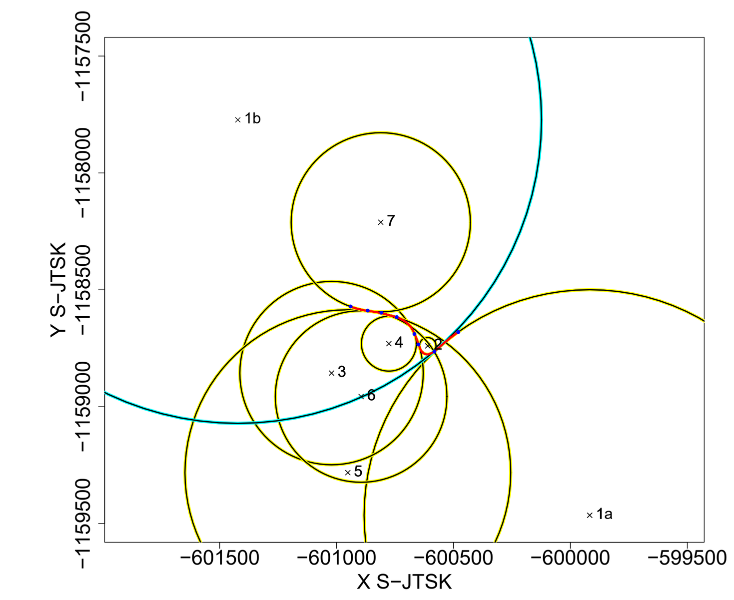

Fig. 2: Radius of location due to least-square cirle fit method.

Data Preprocessing

1. trim of data (same start, resp. end location of each drive)
2. identification of expressway ramps directions
3. interpolation of data by spline functions (determination of the cumulative distance, speed, derivatives of speed)
4. identification of the breakpoints of expressway ramps curvatures
5. transformation of WGS84 [degrees] to S-JTSK [m] coordinates
6. application of the „least-square circle fit" method for calculation of a curvature and a radius of fitted circles, containing above identified breakpoints

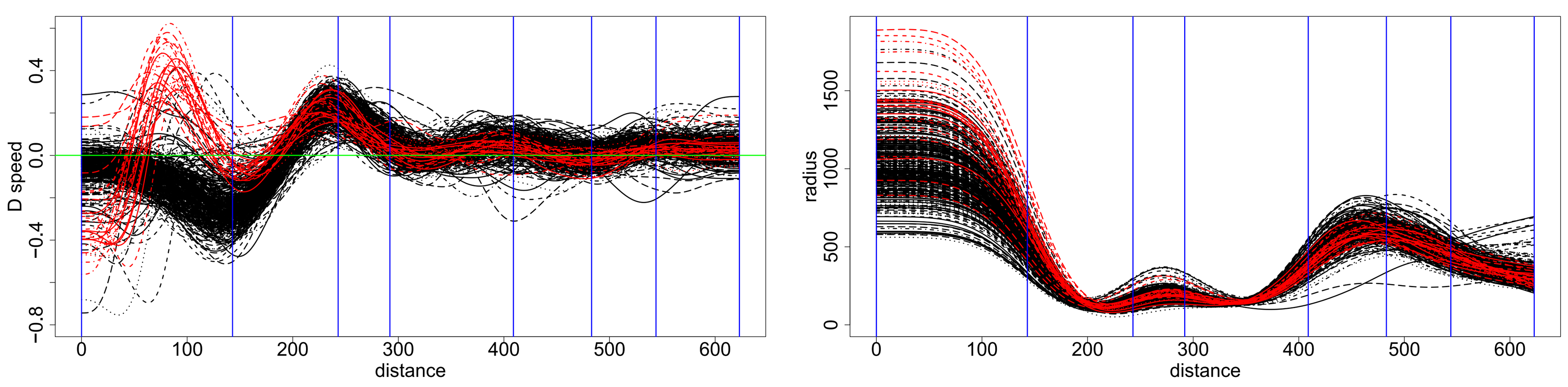

Fig. 3: Derivatives of speed (left), radius (right) depending on distance.

METHODOLOGY

Speed as Functional Observation

- the vehicles speed modelling as a function of a distance
- B-spline basis system specification with 100 cubic spline basis functions and equispaced knots
- further smoothing of the curves of speed by the penalized sum of squared errors
- radius preprocessing in a similar way

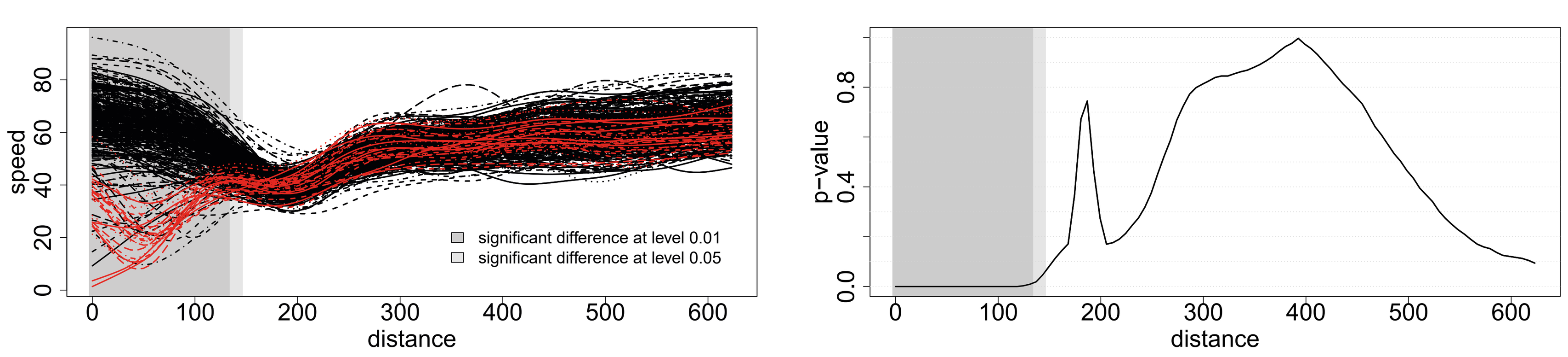

Fig. 4: Comparison of distinct directions (left), adjusted p-values (right).

Testing for Significance in Speed Curves from Different Directions

- application of interval-wise testing procedure [1]
- testing the hypothesis $H_0 : \mu_1(t) = \mu_2(t)\ \forall t \in T$, against $H_1 : \mu_1(t) \neq \mu_2(t)$ for some $t \in T$, using the test statistic

$$T^I = \frac{1}{|I|} \int_{|I|} |\bar{y}_1 - \bar{y}_2|^2 \, dt,$$

where $y_{1i}(t)$, $i = 1,\dots,n_1$ and $y_{2i}(t)$, $i = 1,\dots,n_2$, denote the functional observations from the two groups, $\mu_1(t)$ and $\mu_2(t)$ are their functional mean and I denotes the sub-interval of T and $\bar{y}_j$, $j = 1,2$ is the functional mean of the j-th group.

Variable Selection

Finding the most important predictors using the backward elimination method based on the leave-one-out cross-validation from the set:

- merging lane - factor
- air temperature - factor
- relative humidity [%] - continuous
- rainfall [mm] - continuous
- snow cover [cm] - continuous
- radius [m] – functional

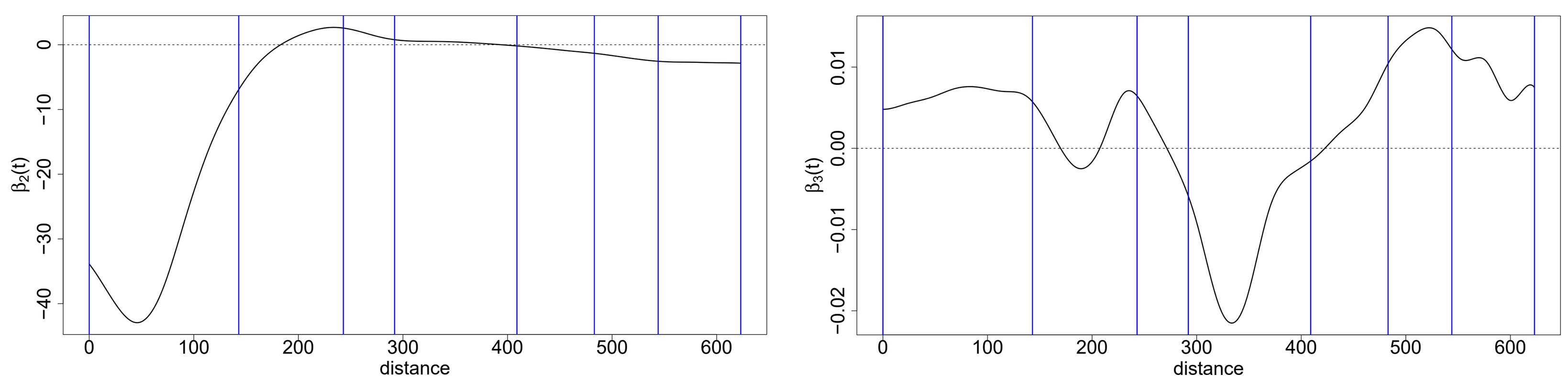

Fig. 5: Contribution of the regression parameters - merging lane (left), radius (right).

The Global Permutation Test for Regression Significance

- testing the hypothesis $H_0 : \beta_l(t) = 0\ \forall l \in S$, $\forall t \in T$ against $H_1 : \beta_l(t) \neq 0$ for some $l \in S$ and some $t \in T$, using the statistic

$$F(t) = \frac{Var(\hat{y}(t))}{\frac{1}{n}\sum (y_i(t) - \hat{y}_i(t))^2}$$

where $\hat{y}_i(t)$ are the fitted values [2]

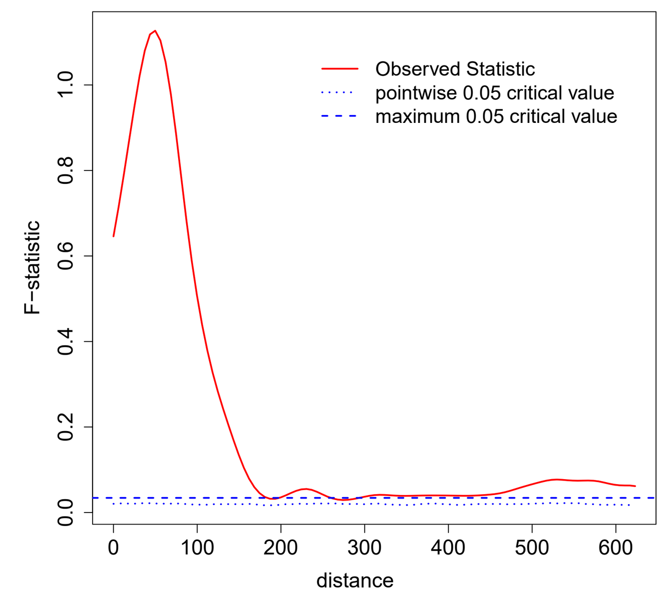

Fig. 6: Permutation F-Test.

RESULTS

The vehicles going from the merging lane (red) has significantly higher acceleration and lower speed, than vehicles from the central lane (black) before approximately 140 meters. In contrary to that, the vehicles cannot be distinguished after that location, see Fig. 3, 4. Moreover the speed of the vehicles can be described by the regression model:

$$Y_i(t) = \beta_0(t) + \beta_1(t) \cdot humidity + \beta_2(t) \cdot merging\ lane_i + \beta_3(t) \cdot radius(t) + \varepsilon_i(t)$$

The significance effect of the above mentioned predictors (Fig. 5) was verified by the F-test, see Fig. 6.

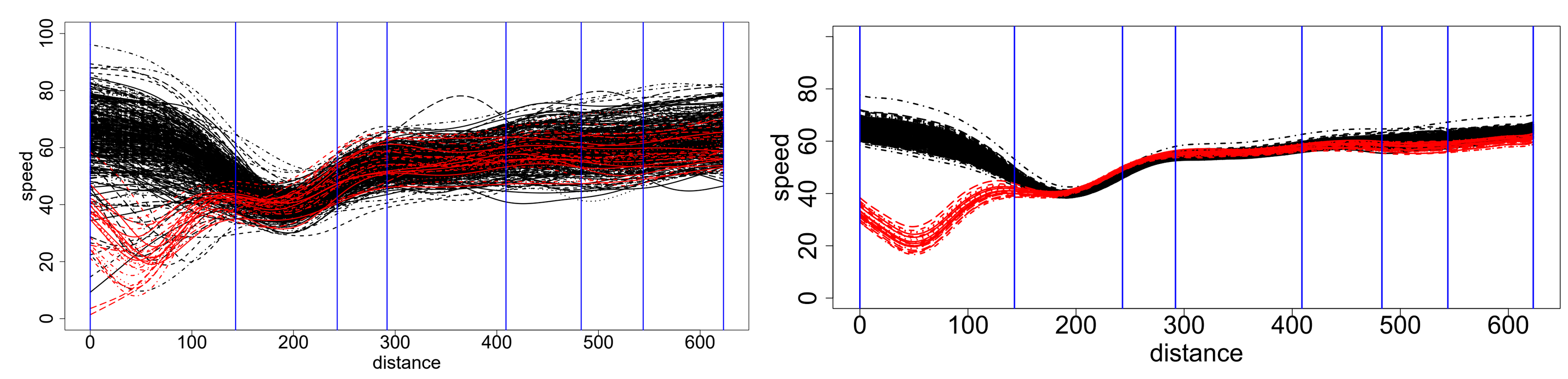

Fig. 7: Speed of functional observations (left), fitted values (right) depending on distance.

CONCLUSIONS

The analysis of the floating car data was performed. Due to occurred data structure, the FDA techniques were employed. Firstly, the effect of the merging lane on speed was examined and proved. Secondly, more predictors were considered. Based on the backward elimination method, the regression model contained these predictors: merging lane, radius and humidity. Finally, the model significance was verified by the F-test.

REFERENCES

[1] Pini, A., & Vantini, S. (2017). Interval-wise testing for functional data. Journal of Nonparametric Statistics, 29 (2), 407-424.

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