Distribution Model of Curve Negotiation Velocity Based on Naturalistic Driving Data

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This study proposes a model for predicting curve negotiation velocity and its distribution. To avoid lane departure accidents in curves, numerous researchers have attempted to develop models for predicting curve-passing velocity. Many of them concentrated on high-speed highway driving situations to avoid accidents. In contrast, few researchers have investigated slower curve passing on ordinary roads. Investigation of such slower driving is, however, also important for driver's comfort and feeling of safety that can indirectly reduce driver's dangerous behavior. The difficulty for investigating this is that traffic phenomena on ordinary roads include various disturbances that are irrelevant to effects of curves. To overcome this difficulty, it is necessary to examine many curves and trips to cancel such irregularities.

The present analysis was based on naturalistic driving data on ordinary roads obtained from the "Driving Behavior Database" distributed by Human Engineering for Quality Life (HQL) in Japan, which incorporates 2300 trips of nine courses of public roads in and around Tsukuba City near Tokyo driven by 4 to 28 voluntarily participants who drove passenger cars with measurement equipment concealed so as not to disturb natural driving. From the database, 42 curves (23 right turns and 19 left turns) were selected for analysis, and there were 265 to 316 trips for each curve. The analysis indicated that both vehicle velocity at the entrances of curves and minimum velocity in the curves can be predicted using two curve characteristics, the mean ~~radius of~~ curvature radius and the newly proposed "velocity tendency."

Velocity seems to be influenced by curves as well as other road conditions such as road-surface state and traffic density. "Velocity tendency" is introduced as a virtual velocity around a curve if the curve did not exist and thus implicitly represents various velocity-reducing factors irrelevant to the nature of the curve. Velocity tendency is a virtual value and was estimated as a mean of peak velocities of straight sections both before and after the curve.

A multivariate, nonlinear regression model was used; the obtained prediction equations are as follows. For minimum velocities,

$v = \alpha * v_{tendency} * (1- \exp(-R/(\beta * v_{tendency})))$, where $\beta = 0.78$ (estimated SD: 0.01) ,

and where v is the minimum velocity to be predicted, R is the mean curvature radius of a curve, $v_{tendency}$ is the usual velocity for the curve, and α and β are shape parameters. The form of the equation means that if the curvature radius increases, v converges to $\alpha * v_{tendency}$. The parameter α describes the distribution of velocities at a minimum velocity point obtained using the following equation where p is a given distribution percentile. In the equation, "cnd" is a cumulative normal function.

$p = \text{cnd}(\alpha; \alpha_{mean}, \alpha_{sd})$,

where $\alpha_{mean} = 0.98$ (estimated SD 0.0008) , and $\alpha_{sd} = 0.14$ (estimated SD 0.001) .

Model prediction errors were within 3km/h standard deviation in almost all percentiles. Actual and predicted distributions at three curves are plotted in Fig. 1.

The same regression was applied for curve entrance velocities, and parameters $\beta = 0.51$, $\alpha_{mean} = 0.97$, and $\alpha_{sd} = 0.14$ were obtained. This model also produced a good fit to actual distributions.

The performance of these regression models suggests that factors affecting speed selection can be generally separated into geometric features of a curve, velocity around the curve, and other unknown factors. Some curves still yield rather large prediction errors, suggesting that there are other factors to be investigated.

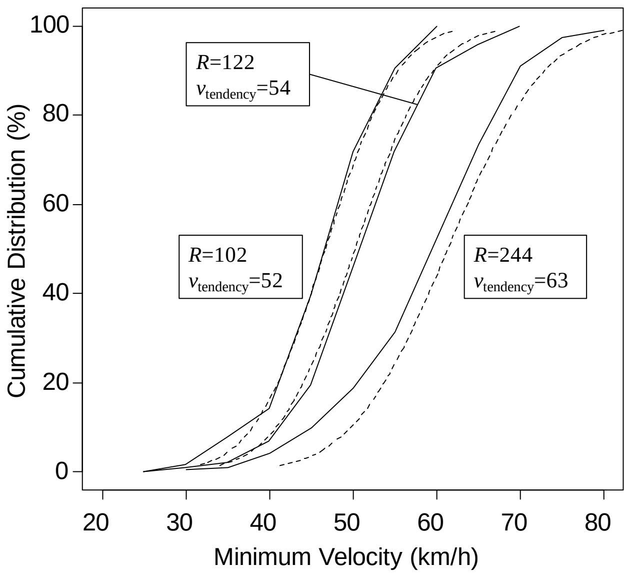

Fig. 1 Examples of Cumulative Distribution of Minimum Velocity in Three Curves, Actual (solid) and Predicted (dotted)

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