

Driver Accelerator Prediction using Real-World Environmental Parameters: Integrating a Brake Prediction Mechanism

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Vehicle simulation is widely used in vehicle development to evaluate vehicle performance and control systems. Driver behavior is particularly important because differences in driving operation can affect vehicle motion, energy consumption, and emissions. However, many conventional driver models predict vehicle speed or acceleration rather than the driver's actual accelerator and brake operations. Previous studies have modeled accelerator and brake operations or braking decisions from traffic conditions, but the predicted braking decision has rarely been directly incorporated into accelerator prediction. Therefore, this study proposes a driver model that predicts brake-operation probability and accelerator-pedal position in parallel and incorporates the predicted brake probability into accelerator prediction through a gating mechanism. In addition to overall prediction accuracy, state-specific performance is evaluated to assess the model from the perspective of vehicle-simulation applications.

Real-world car-following experiments were conducted using a leading and following vehicle driven by three following-vehicle drivers. The model uses six traffic-environment parameters: leading-vehicle speed, leading-vehicle acceleration, relative speed, relative acceleration, inter-vehicle distance, and road gradient. Using 5.0 sec of past data sampled at 10 Hz, the model predicts accelerator-pedal position and brake-operation probability 0.1 s ahead. The basic TL model consists of a Transformer-based brake-prediction branch and an LSTM-based accelerator-prediction branch. The two outputs are combined by a gating mechanism, in which a higher predicted brake probability suppresses the accelerator output. This propagates the accelerator loss to both branches, so the brake decision directly affects accelerator-prediction learning. In addition, a PT-TL_{sp} model was developed using a two-stage training strategy. In the first stage, the two branches are trained independently with a relatively strong stopping penalty applied to the accelerator branch. In the second stage, the branches are integrated and fine-tuned with a weaker stopping penalty.

The combinations of LSTM and Transformer predictors were first compared. The TL model, using a Transformer for brake prediction and an LSTM for accelerator prediction, achieved the highest overall accelerator. However, the model with the highest brake F1 score did not achieve the highest accelerator, indicating that brake-classification performance alone does not determine the final accelerator-prediction performance. This is because the gating mechanism uses continuous brake probability rather than a binary brake decision. The TL model was therefore selected as the basic configuration and further evaluated for stopping-transition, stationary, and launch states.

State-specific evaluation revealed that the TL model improved overall accelerator prediction and stopping-transition performance compared with an accelerator-only LSTM, while stationary performance deteriorated. This result indicates that overall metrics alone may overlook local prediction errors that are important for vehicle simulation. In particular, false accelerator output during a stationary period may produce unnecessary driving force, while timing errors during stopping or launch may affect subsequent vehicle motion. The stopping penalty and independent pretraining were therefore introduced. When applied individually, these methods improved stationary and launch performance but reduced overall accuracy. In contrast, the PT-TL_{sp} model limited the reduction in overall accelerator to approximately 0.4% relative to the TL model, while reducing the stationary false-acceleration rate by approximately 36.9%, stationary accelerator RMSE by 22.5%, and launch timing MAE by 25.6%. The two-stage training strategy is considered to retain the stationary and launch performance obtained through the stopping penalty and independent pretraining while mitigating excessive accelerator suppression during integrated training.

These results demonstrate that the PT-TL_{sp} model provides a better balance between overall prediction accuracy and state-specific performance than the other evaluated models. They also show that state-specific metrics are important when evaluating driver models for vehicle-simulation applications, because high overall accuracy does not necessarily guarantee appropriate behavior during stopping and launch. Future work will evaluate generalization to unseen drivers and apply the proposed model to a vehicle simulator to investigate its effects on vehicle motion, energy consumption, and emissions.

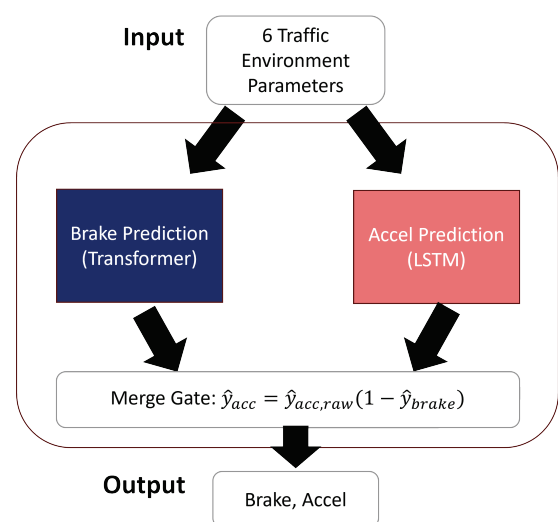


Fig.1 Architecture of the Proposed Driver Model