Using Cooperative ACC to Form High-Performance Vehicle Streams

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Background

- Funded under FHWA Exploratory Advanced Research Program Solicitation, 2013 (Topic 1A)
- Problem to be addressed: to understand the impacts that progressive market penetration of ACC (Adaptive Cruise Control) and CACC vehicles will have on traffic.
- Previous work developed a simple ACC & CACC following model based on field test data.
- This model is very useful for microscopic simulation since it behaves similarly to the real ACC & CACC vehicles' feedback control for speed range between 50–65 mph.

Project Goals

- Define protocols for formation and separation of CACC clusters for maximum traffic benefits
- Develop protocols for CACC association with "correct" other vehicles in same lane
- Integrate CACC with managed lane operations
- Estimate realistic traffic impacts of CACC using empirically-derived car following models
- Cross-validate PATH and TU Delft simulation tools

Refined ACC & CACC Algorithm for Simulation

Limitation of the model: initial implementation outside its derived speed range in the Aimsun microscopic simulation had some overshoots (ACC and CACC vehicles hitting forward vehicle).
- Model refinement: through control gain scheduling

ACC Algorithm Refined Based on Work in [1]

\[ d_{acc}(k) = -0.07(v_{ref}(k-1) - v_{k-1}(k-1)) + 0.23(v_{ref}(k-1) - d_{acc}(k-1) - v_{k-1}(k-1)) \]
\[ d_{acc}(k) = \max[\min[-0.4(v_{ref}(k-1) - v_{k-1}(k-1)), 0.098] - 2.8] \] (intermediate parameters)
\[ a_{acc}(k-1) = 0.28 \leq a_{acc}(k) \leq a_{acc}(k-1) + 0.098 \]

\( k \) – time step

\[ d_{acc}(k) = x_{ACC}(k-1) - x_{ACC}(k-1), \] (distance between vehicles)

If \( a_{acc}(k) > 0 \), the gains are reduced as follows

\[ a_{acc}(k) = \begin{cases} 0.90a_{acc}(k) & 30.0 < d_{acc}(k) \leq 50.0 \\ 0.75a_{acc}(k) & 20.0 < d_{acc}(k) \leq 30.0 \\ 0.50a_{acc}(k) & 15.0 < d_{acc}(k) \leq 20.0 \\ 0.30a_{acc}(k) & 10.0 < d_{acc}(k) \leq 15.0 \\ 0.20a_{acc}(k) & 5.0 < d_{acc}(k) \leq 10.0 \\ 0.10a_{acc}(k) & d_{acc}(k) \leq 5.0 \end{cases} \]

CACC Algorithm Refined Based on Work in [1]

\[ d_{cacc}(k) = x_{ACC}(k-1) - x_{ACC}(k-1), \] (distance to the front vehicle)

\[ e_{cacc}(k-1) = x_{ACC}(k-1) - x_{ACC}(k-1) - v_{cacc}(k-1), \] (distance error)

\[ e_{cacc}(k) = x_{ACC}(k) - x_{ACC}(k-1) - v_{cacc}(k-1) - v_{cacc}(k-2) \]
\[ e_{cacc}(k-2) = x_{ACC}(k-1) - x_{ACC}(k-2) - v_{cacc}(k-2) \]
\[ e_{cacc}(k-3) = x_{ACC}(k-2) - x_{ACC}(k-3) - v_{cacc}(k-3) \]

\[ v_{cacc}(k) = \max[\min[\{v_{cacc}(k), v_{cacc}(k-1) + \Delta \gamma, v_{cacc}(k-1) - 2.0 \Delta \gamma\}]] \]

\( v_{cacc}(k) \) – desired speed

\( \alpha, \beta, \gamma \) – gains to be selected based on distance to front vehicle

Aimsun Implementation of the Algorithms

- ACC and CACC algorithms are implemented in microscopic simulation in Aimsun for a 13 mile section of the SR-99 freeway Northbound near Sacramento with HOV lanes. Vehicle types and car-following models include:
  - ACC: developed ACC algorithm is used
  - CACC: developed CACC car-following algorithm is used;
  - Manually driven: trucks, passenger cars, and HOV vehicles, and vehicles with VAD (Vehicle Awareness Devices)

Lane change: using Aimsun default model

Time gap selection:

- Simple empirically-derived algorithms for ACC & CACC following developed for microscopic simulation have been extended to full speed range.

Next steps: (a) further refine the algorithms, (b) develop lane changing models relevant to ACC and CACC; (c) model string clustering strategies; (d) define other microscopic maneuvers; (e) evaluate impacts on traffic flow and potential benefits.

Reference