Modeling Cooperative Lane-changing and Forced Merging Behavior

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Outline

• Motivation
• Model structure
• Preliminary estimation results
• Next steps
Motivation

• Driving behavior models are key elements in microscopic traffic simulation tools

• Limitations of the state-of-the-art merging models
  – Based on reactive behavior
  – Ignore driver cooperation and courtesy
  – Forced merging modeled separately

• Applications of such models may result
  – Unrealistic traffic flow characteristics
  – Over predict congestion
Merging Behavior

- Vehicle merging
  - Lane changing through gap acceptance
  - Models fail in dense traffic
- Additional merging mechanisms
  - Lag vehicle may provide courtesy
  - Vehicle may force a lane change
Proposed Model

• Explicitly includes anticipation of the behavior of other drivers in the decision making process of a particular driver
• Has the flexibility to capture cooperative behavior among drivers
Proposed Model (cont.)

• Integrates forced merging in the general decision framework
Proposed Model (cont.)

- Stochastic model with state dependency and serial correlation along a trajectory
- Transition from normal to cooperative or forced merge is endogenous
Framework

Target Lane

Normal Gap Acceptance

Gap Anticipation

Initiate Courtesy Merging

Deceleration Anticipation

Initiate Forced Merging

Courtesy/Forced Merging Gap Acceptance

MLC to target lane

adjacent gaps acceptable

adjacent gaps not acceptable

anticipated gap

initiate courtesy merge

do not initiate courtesy merge

anticipated deceleration

initiate forced merge

do not initiate forced merge

change

no change

change

no change

change

no change
Available Gap

- Adjacent gap changes if either lead or lag vehicle changes
Gap Acceptance

Target Lane

Normal Gap Acceptance
- adjacent gaps acceptable
- adjacent gaps not acceptable

Gap Anticipation

Initiate Courtesy Merging

Deceleration Anticipation

Initiate Forced Merging

Courtesy/Forced Merging Gap Acceptance
- change
- no change

MLC to target lane

Initiate courtesy merge
- anticipated deceleration
- initiate forced merge
- do not initiate forced merge

Do not initiate courtesy merge

New Adjacent Gap
- change
- no change

Same Adjacent Gap
- change
- no change

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Gap Acceptance (cont.)

- Target lane of the merging driver is the rightmost lane of the mainline
- Driver evaluates lead and lag gaps
- Changes lanes if both gaps are acceptable
- Acceptable gap
  - available gap ≥ critical gap
**Courtesy Merging**

- **Target Lane**
  - **Normal Gap Acceptance**
    - adjacent gaps acceptable
    - adjacent gaps not acceptable
      - anticipated gap
      - do not initiate courtesy merge
    - initiate courtesy merge
      - same adjacent gap
      - new adjacent gap
    - initiate forced merging
      - anticipated deceleration
      - do not initiate forced merge
  - Gap Anticipation
  - Initiate Courtesy Merging
  - Deceleration Anticipation
  - Initiate Forced Merging
  - Courtesy/Forced Merging Gap Acceptance
    - change
    - no change
    - change
      - same adjacent gap
      - new adjacent gap
    - no change
      - same adjacent gap
      - new adjacent gap
    - change
      - same adjacent gap
      - new adjacent gap
    - no change
Courtesy Merging (cont.)

- Driver anticipates future gap
  - Latent time horizon $\tau_n$
- Critical gap may differ from normal gap acceptance
- Anticipated gap
  - Acceptable : Initiate lane change through courtesy
  - Not acceptable: Consider initiating forced merge
- Unacceptable available gaps may delay the execution of the courtesy lane change
Forced Merging

Target Lane

Normal Gap Acceptance

Gap Anticipation

Initiate Courtesy Merging

Deceleration Anticipation

Initiate Forced Merging

Courtesy/Forced Merging Gap Acceptance

MLC to target lane

adjacent gaps acceptable

adjacent gaps not acceptable

initiate courtesy merge

initiate forced merge

no change

change

no change

change

anticipated gap

anticipated deceleration

same adjacent gap

new adjacent gap

same adjacent gap

new adjacent gap

no change

change

no change

change

no change
Forced Merging (cont.)

- Driver evaluates the feasibility to initiate a forced merge
  - Anticipated deceleration and stopping distance of the lag vehicle
- Anticipated deceleration/stopping distance
  - Acceptable: Initiate forced merge
  - Not acceptable: Remain in normal merging state
- Unacceptable available gaps may delay the execution of the forced lane change
Modeling Issues

• Can a simpler model be equally effective?
• Two simplified structures
  1. Combine all lane changing types in a one stage model including variables that capture courtesy and forced merging
  2. Combine normal and courtesy merging and treat only forced merging separately
Alternative Model 1

• Maintain structure of gap acceptance models
  – Incorporate variables that capture courtesy and forcing
    • e.g. acceleration of lag vehicle, remaining distance to end of ramp, delay, density etc.
Alternative Model 2

- Explicitly model forced merging
- Capture courtesy via variables in gap acceptance model
  - e.g. acceleration of lag vehicle etc.

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Target Lane

Forced Merging

Normal Gap Acceptance
adjacent gaps acceptable
adjacent gaps not acceptable

MLC to target lane

initiate forced merge
do not initiate forced merge

Forced Merging Gap Acceptance
change

Same Adjacent Gap

New Adjacent Gap

no change
change
no change

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NGSIM I-80 Study Area

1650 ft = 502.92m

EB I-80

1 2 3 4 5

11.8ft = 3.6m

24ft = 7.3m shoulder

7 Powell St. On-Ramp

8 Ashby Off-Ramp

Study Area of Trajectory Data
Estimation Data Set

- 45 minute data
- 592 merging vehicles
- X and Y coordinates every 1/10th sec
- Estimation based on 17230 observations
- Summary statistics
  - Average speed of merging vehicles 14.6 km/hr
  - Average speed in Lane 6 16.3 km/hr
  - Average density in Lane 6 68.2 veh/km/lane
Preliminary estimation results

• Critical lead and lag gaps
  – Decrease with remaining distance to end of ramp
  – Increase with average speed of the mainline and speed of lag vehicle
• Significantly better fit with more detailed model structures
Conclusion

• Next Steps
  – Implement in MITSIMLab
  – Calibrate and validate using aggregate sensor data

• Future Research
  – Incorporate
    • Target gap selection
    • Acceleration to facilitate merging
Questions?