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Measuring Semi-Automated Vehicle Behavior from Field Data

Noah J. Goodall, Ph.D., P.E.

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ACC as AVs

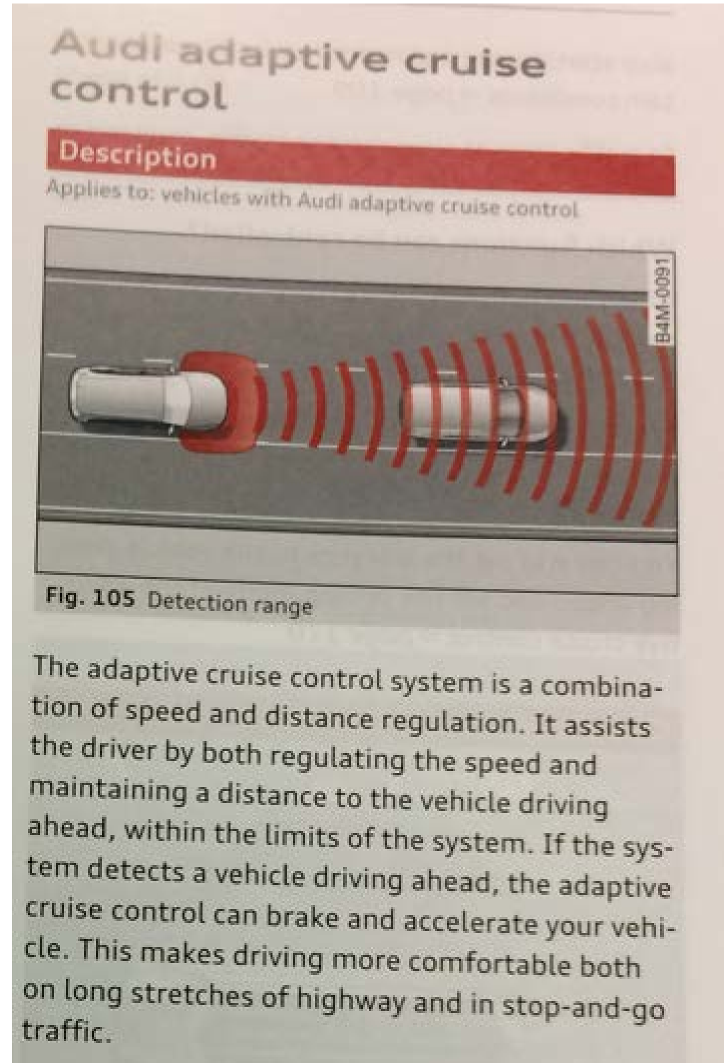
- Automated vehicles will have profound effects on capacity
- Need accurate models of their car-following behavior
- Production adaptive cruise control (ACC) systems might drive similar to future Avs
- Actual ACC algorithms are trade secrets
- Must create from field data

Modeling AV Behavior

- VDOT leased an Audi Q7 with adaptive cruise control
- VTRC measured performance of ACC in traffic

ACC and Traffic Jam Assist

- ACC
  - Uses video, ultrasound, and radar to maintain headway
  - 650 foot range
- Traffic Jam Assist
  - Gentle acceleration and braking below 40 mph in congestion
  - Must be reactivated at each stop



Audi adaptive cruise control

Description

Applies to: vehicles with Audi adaptive cruise control

Fig. 105 Detection range

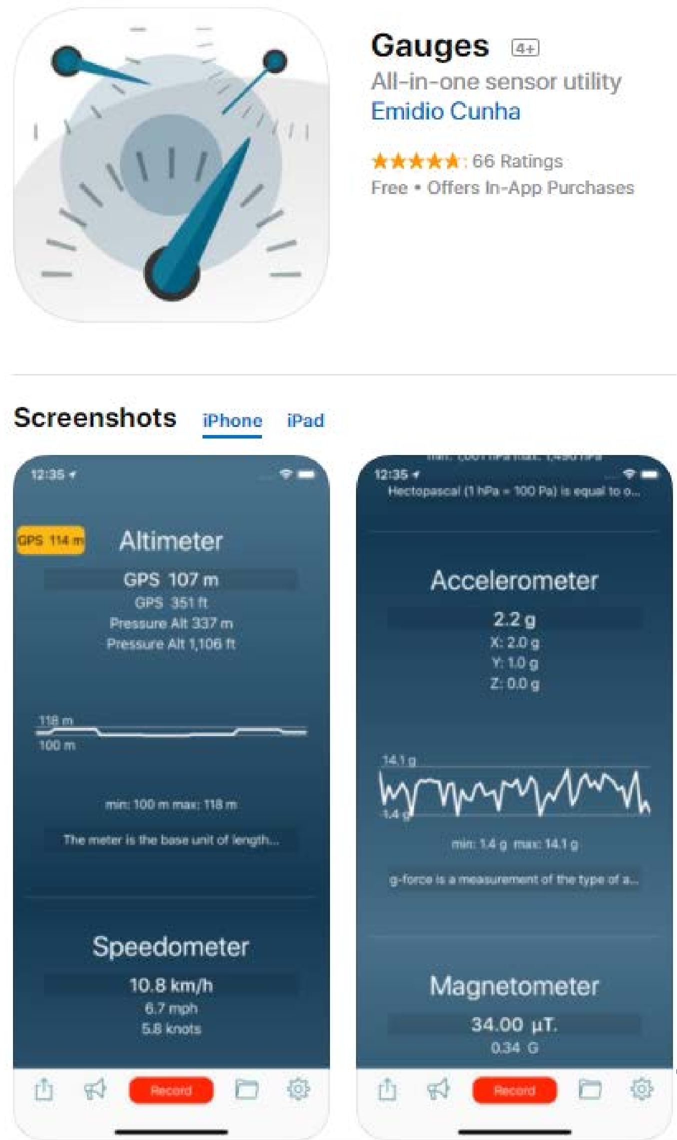
The adaptive cruise control system is a combination of speed and distance regulation. It assists the driver by both regulating the speed and maintaining a distance to the vehicle driving ahead, within the limits of the system. If the system detects a vehicle driving ahead, the adaptive cruise control can brake and accelerate your vehicle. This makes driving more comfortable both on long stretches of highway and in stop-and-go traffic.

Video of Dash and Traffic

Following Distance – Laser Range Finder

Speed and Acceleration

- GPS unit
- Smartphone GPS and internal accelerometer



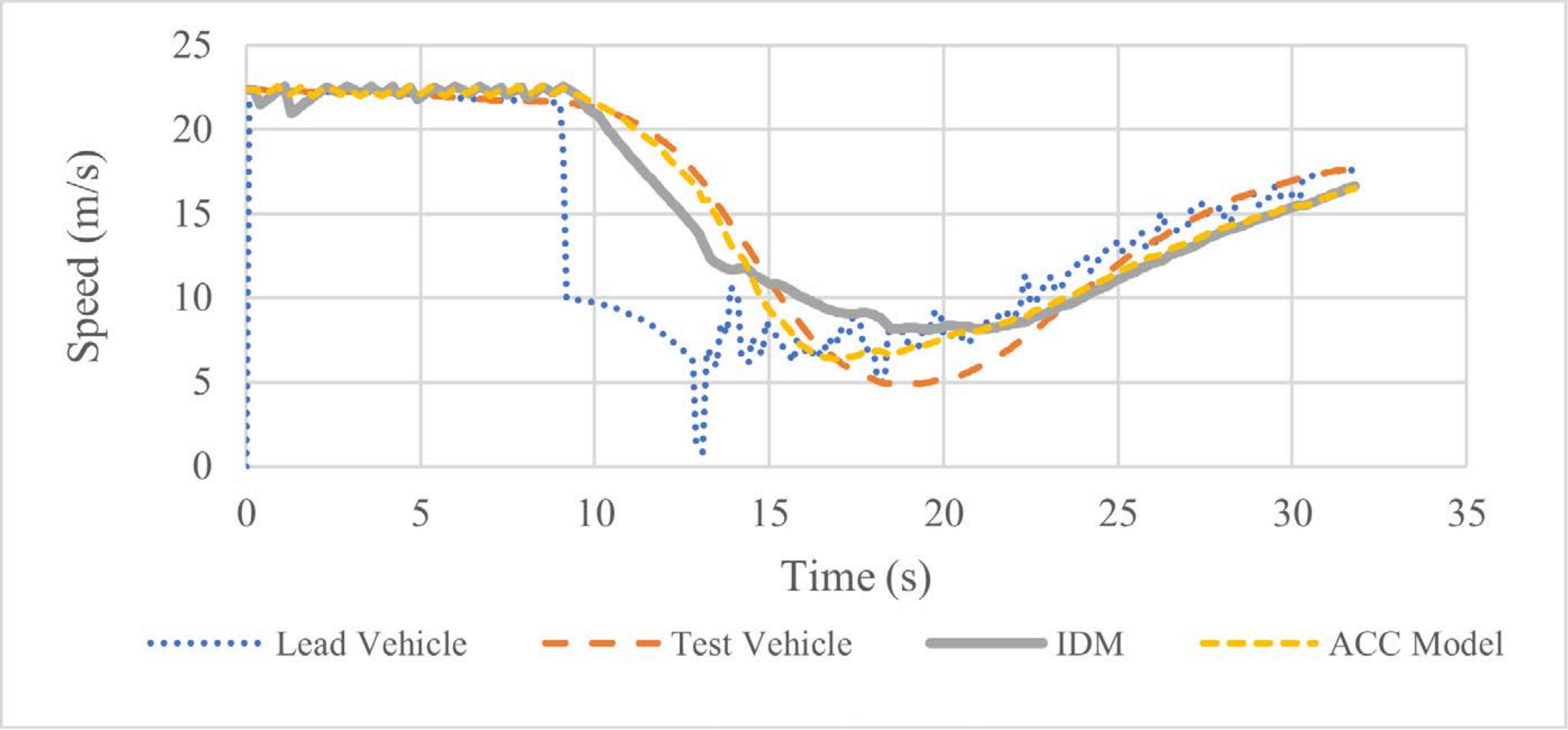
Intelligent Driver Model

$$a_{IDM} = a\left[1 - \left(\frac{v}{v_0}\right)^{\delta} - \left(\frac{s_0 + max\left[0, vT + \frac{v\Delta v}{2\sqrt{ab}}\right]}{s}\right)^2\right]$$

$$a_{IDM} = \begin{cases} j_{max} + a_{t-r}, & a_{IDM} - a_{t-r} < j_{max} \\ 2rb_{max} - \sum_{i=t-1}^{t+1-2r} a_i\,, & \frac{1}{2r}\left(a_{IDM} + \sum_{i=t-1}^{t+1-2r} a_i\right) < b_{max} \\ a_{IDM}, & otherwise \end{cases}$$

$$a_{CAH} = \begin{cases} \frac{v^2 \tilde{a}_l}{v_l^2 - 2s\tilde{a}_l}, & v_l(v - v_l) \le -2s\tilde{a}_l \\ \tilde{a}_l - \frac{(v - v_l)^2\, \Theta\,(v - v_l)}{2s}, & otherwise \end{cases}$$

Instead, a Figure:
Test Vehicle vs. IDM vs. ACC Model



More details in the paper

Applications for VISSIM

- Several papers use VISSIM to model vehicles with ACC
  - Wiedemann 99 rather than 74
- Four model attributes were directly measured in this study

Acceleration from Standstill

- Needed for most models
- VISSIM needs acceleration at 80 km/hr
- Audi acceleration tested using ACC set to 60 mph (100 km/hr) from standstill

Vehicle Speed *(km/hr)*	0	10	20	30	40	50	60	70	**80**	90
Average Acceleration *(m/s^2)*	0.36	2.02	2.10	2.66	2.36	2.01	1.75	1.53	**1.17**	0.57

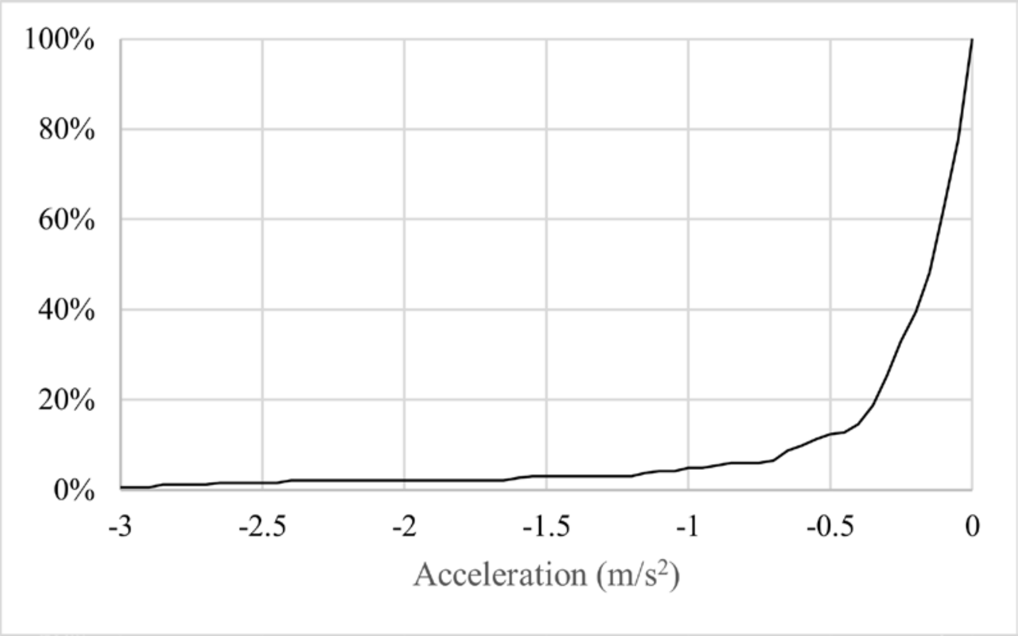
Startup Time and Distance

- Time between when the lead vehicle moves and the ACC vehicle moves in a queue
- In VISSIM this is *longitudinal oscillation*

Measure	**Average Value**
Time between lead brake light off and ACC vehicle movement	2.48 s
Time between lead vehicle movement and ACC vehicle movement	1.59 s
Distance traveled by lead vehicle distance before ACC vehicle movement	1.73 m

Deceleration

- ISO 15622 limits decelerations to –3 m/s^2.
- 98% of observed decelerations below desired deceleration of –2 m/s^2 in the literature



Standstill Distance

- Gap between bumpers in a stopped queue
- 8 instances between 3.35 and 4.2 meters
- Distance of **3.5 meters** used as model input

Recommended VISSIM Settings

Wiedemann 99 Parameter	Description	Recommended Value
CC0	**Standstill distance:** The desired gap between two stationary vehicles. *Observed distance was 3.5 m.*	3.5 m
CC1	**Following distance:** The minimum desired time gap between two vehicles. *The manufacturer's default following distance was 1.8 s, although this should be altered based on known or estimated settings.*	1.8 s
CC2	**Longitudinal oscillation:** The gap distance beyond the minimum safety distance at which a vehicle will accelerate to a leading vehicle. *Test vehicle set at 1.8 s following distance would accelerate when following distance exceeded 1.9 s at speeds of 15-20 m/s, resulting in a value of 1.5 to 2.0 meters.*	2.0 m
CC3	**Perception threshold for following:** The number of seconds prior to which reaching a safety distance at which deceleration begins, expressed as a negative value. *This could not be determined from the empirical data, and so the VISSIM default was used as recommended in the literature (5, 6).*	-8.0 s
CC4	**Negative speed difference:** Threshold for negative difference in speed between leading and following vehicle for reaction during the following regime. *Values closer to zero result in more sensitive reactions to changes in lead vehicle speed. Using default value as recommended in the literature (5, 6).*	-0.35 m/s
CC5	**Positive speed difference:** Threshold for positive difference in speed between leading and following vehicle for reaction during the following regime. *Values closer to zero result in more sensitive reactions to changes in lead vehicle speed. Using default value as recommended in the literature (5, 6).*	0.35 m/s
CC6	**Influence speed on oscillation:** Measure of the impact of gap on speed oscillation, with larger values producing greater speed oscillation at longer gaps. *Using values recommended in the literature (5, 6).*	0 / (m·s)
CC7	**Oscillation during acceleration:** Limits the jerk during the first time step while a vehicle is in the free regime. *Value is taken from observations of the test vehicle's initial acceleration when starting from standstill with no leading vehicle.*	0.36 m/s^2
CC8	**Acceleration starting from standstill:** Desired acceleration when starting from standstill. *Value taken from maximum allowable acceleration in ISO 15622 (4).*	2.00 m/s^2
CC9	**Acceleration at 80 km/hr:** Desired acceleration at 80 km/hr, limited by vehicle engine. *Value taken from acceleration tests.*	1.17 m/s^2

Sources for Default Values

4) ISO. *ISO 15622:2010(En), Intelligent Transport Systems — Adaptive Cruise Control Systems — Performance Requirements and Test Procedures*. Publication ISO 15622:2010. International Organization for Standardization, Geneva, Switzerland, 2010.

5) Bierstedt, J., A. Gooze, C. Gray, J. Peterman, L. Raykin, and J. Walters. *Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity*. FP Think Working Group, 2019.

6) Sukennik, P. *Micro-Simulation Guide for Automated Vehicles*. Publication D2.5 v1.0. European Union's Horizon 2020 Research and Innovation Programme, 2018.

Conclusions

- Four attributes of production ACC measured from field data
- Recommended values for VISSIM Wiedemann 99 model provided from field data and literature

For More Details

- Paper, with Chien-Lun Lan
  - Draft, under review
  - Email me for a copy noah.goodall@vdot.virginia.gov
- TRB Poster 20-05590

http://people.virginia.edu/~njg2q/acc_modeling_poster.pdf

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Questions

Noah Goodall
noah.goodall@vdot.virginia.gov