A first car following model

CE 391F

March 21, 2013

ANNOUNCEMENTS

- Homework 3 to be posted this weekend
- Course project abstracts “due” Tuesday

REVIEW

Driver characteristics...

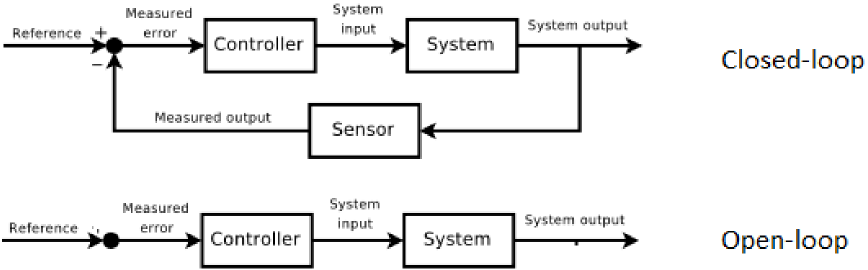
- Reaction time and control time
- Visual ability and perception
- Differences among drivers

OUTLINE

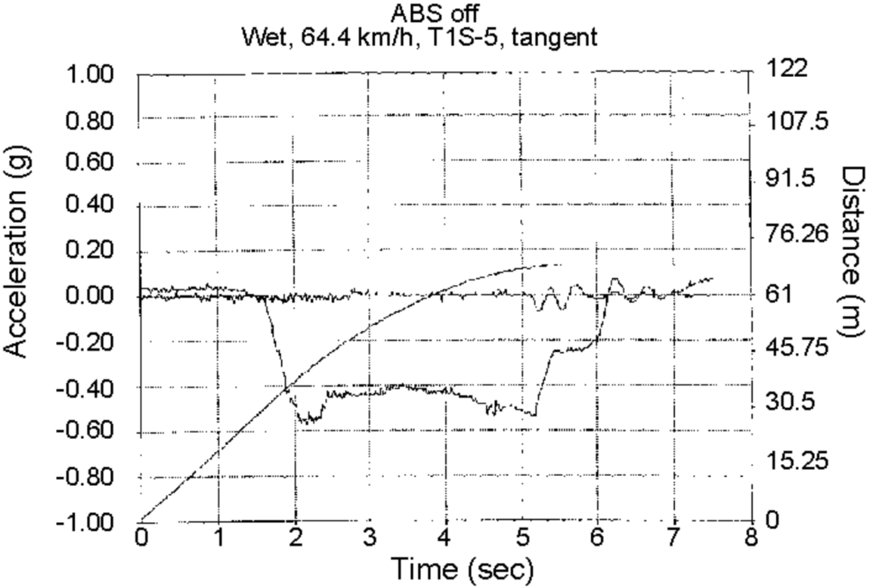
1. Typical braking and acceleration rates
2. A first car-following model

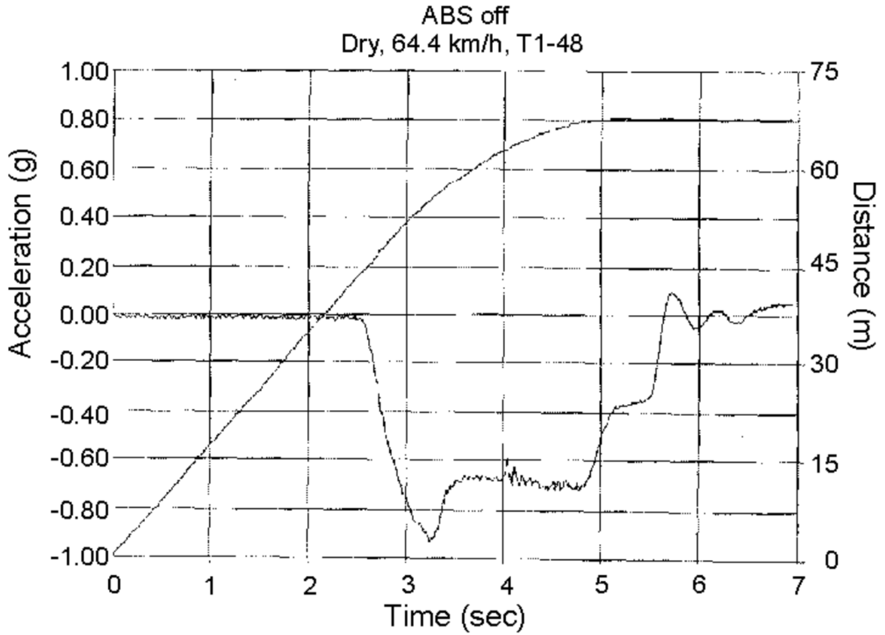
BRAKING AND ACCELERATION

Remember the difference between open-loop and closed-loop control?



Open-loop braking applies to "panic stops" where the driver simply brakes as fast as possible until stopped.


ABS off
Wet, 64.4 km/h, T1S-5, tangent
Acceleration (g)
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
Distance (m)
122
107.5
91.5
76.26
61
45.75
30.5
15.25
0
0
1
2
3
4
5
6
7
8
Time (sec)


ABS off
Dry, 64.4 km/h, T1-48
Acceleration (g)
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
Distance (m)
75
60
45
30
15
0
0
1
2
3
4
5
6
7
Time (sec)

The classic AASHTO formula for braking distance is $d = V^2/(257.9f)$ where V is speed in kph and f is the coefficient of braking friction, roughly equal to deceleration in g units.

Typical acceleration values for "open-loop" braking is 0.7 g on dry pavement, and 0.4 g on wet pavement.

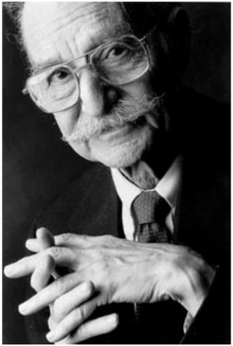
Closed-loop braking is more common, where drivers braking rate is more measured and feedback-dependent.

Comfortable braking acceleration is around 0.2–0.4 g.

"Unhurried" acceleration (0.1 g) is roughly 65% of maximum acceleration.

TOWARDS CAR-FOLLOWING

Robert Herman (1914–1997)



What is a "safe" following distance?

Assume that your speed is V, your reaction time is T, and your maximum deceleration rate is a_f, and...

1. ...the vehicle in front of you stops instantaneously (a very conservative assumption)?
2. ...the vehicle in front of you decelerates to a stop at a rate of a_l?

Drivers must make an assumption about the difference between their deceleration rate and that of the vehicle in front of them; let $\gamma = \left(\frac{1}{2a_f} - \frac{1}{2a_l}\right)$.

Interestingly, this formula implies a capacity rate. How?

With a vehicle length L, the space headways are $L + TV + \gamma V^2$

Thus, the density is $(L + TV + \gamma V^2)^{-1}$

Thus, the flow is $V/(L + TV + \gamma V^2)$.

What is the maximum value of this function?

Any car-following model must make assumptions about how users will behave. As a starting point, let's assume that drivers want to simultaneously:

1. Keep up with the vehicle in front of them
2. Avoid collisions

The simplest way to accommodate both factors is to base our model on *relative speed* $V_{rel} = V_f - V_l$

(Many variations and elaborations have been proposed. Can you think of some ways to extend this model?)

As our starting point, we'll use the linear stimulus-response equation

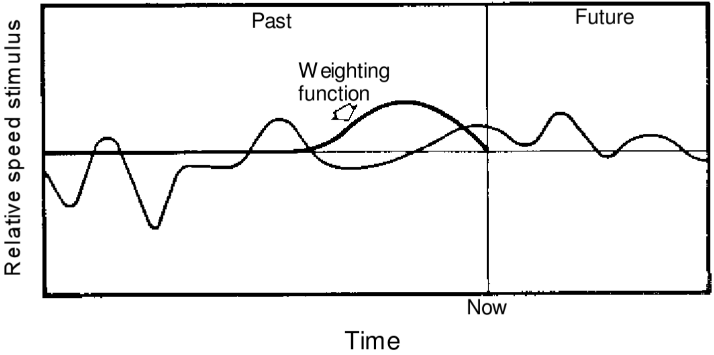
$$R = \lambda S$$

where we need to define S and R as the stimulus and response for car following.

The stimulus S will be based on the relative speeds from the past V_{rel}, based on a weighting function $\sigma(t)$:

$$S = \int_0^{\infty} \sigma(\tau) V_{rel}(\tau) d\tau$$

where τ is going *backward* in time from the present.



$\sigma(t)$ defines the "memory" : how far back do drivers think when driving? What is the most recent information that can be used? and so forth.

$\sigma(t)$ must be a valid probability density function: it should be nonnegative, and integrate to 1 over the positive reals.

One simple option is to set $\sigma(t) = \delta(T)$, where T is the reaction time and δ is the Dirac delta function

This means that the response is based entirely on the relative velocity T seconds ago.

What should the response be?

The accelerator and brake pedals control the *acceleration* of the vehicle, so it is reasonable to define $R = \ddot{x}$

Thus, our first car-following model is simply

$$\ddot{x}(t) = \lambda(\dot{x}(t - T) - V_l(t - T))$$

where V_l is the speed of the lead car, and λ indicates how strongly someone will react to the relative velocity between them and the lead car.

Example

You are traveling at a constant speed of 90 ft/s. A vehicle merges 1000 ft downstream of you, traveling at a constant 60 ft/s. If your reaction time is 2 seconds, plot your trajectory.

Notice what's different about this model from all of our continuum models:

- It's directly based on a driver behavior model
- It is fully anisotropic
- Vehicles are discrete entities
- It is trivial to represent differences in drivers or vehicles by changing acceleration rates, λ, reaction times, etc.