Driver and vehicle performance

CE 391F

March 19, 2013

ANNOUNCEMENTS

- Homework 2 solutions online, to be passed back today
- Homework 3 forthcoming

Course Projects

The type of project I'm looking for:

- Case study using field data and one of the models from class
- Implement one of the models in class in a programming language
- Extending the "signal optimization" CTM homework problem to a larger/more realistic case
- Literature review exploring a certain class of models in more detail

Course projects will be done individually. Feel free to discuss ideas with me, especially if it can be related to your current research.

Prepare a final report (due at the scheduled final exam time) and a presentation (last week of class)

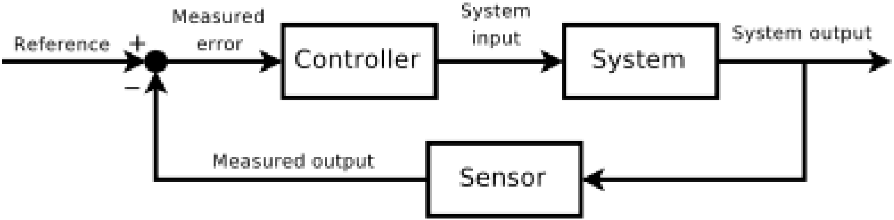
By next Tuesday, send me an abstract of your course project.

VEHICLES AND DRIVERS

Towards car-following

Our goal is to move beyond continuum flow models, respecting the discrete nature of vehicles, and differences among drivers and vehicles.

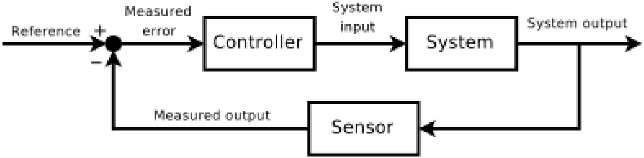
The driving process is a *control problem*: a driver gathers information from the road, dashboard, or technology, processes this information, then controls the vehicle through steering, accelerating, braking, shifting gear, etc.



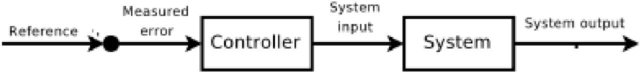
Other types of control problems: thermostats in air conditioning; navigation systems; irrigation sprinklers

In particular, autonomous vehicles have a very different control model, and will lead to different traffic flow theories.

Control problems can be classified as “open-loop” or “closed-loop.” In “open-loop” control, there is *no feedback* after the fact, while in “closed-loop” control the agent can adapt the control based on feedback.



Closed-loop



Open-loop

Driving is typically a “closed-loop” activity, but in a few cases it can resemble open-loop control.

Outline

We'll look at the following topics related to vehicles and drivers:

- Reaction time and control time
- Visual ability and perception
- Differences among drivers
- Typical braking and acceleration rates
- Gap acceptance? (depending on time)

REACTION TIME

What determines a driver's reaction time?

Many factors: age, distraction, physiology/genetics, cognitive load...

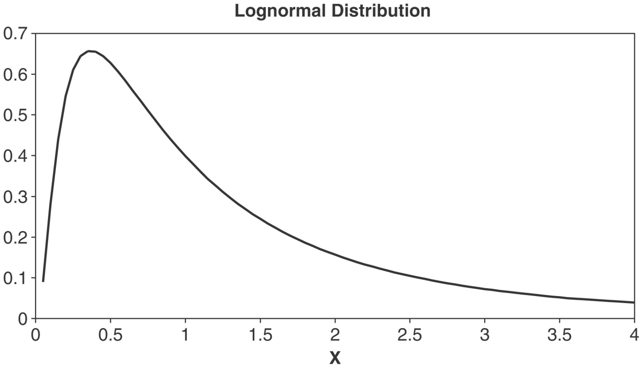
In many choice problems, reaction time follows the Hick-Hyman Law $RT = a + bH$ where H is the logarithm of the number of choices available and a and b are calibrated constants.

Hooper and McGee suggest that driver behavior is different from pure choice problems, because of the inherent sequencing of driving tasks.

What has to happen when someone decides to brake?

Action	Time (s)	Cumulative time (s)
Latency	0.31	0.31
Eye movement	0.09	0.40
Fixation	0.20	0.60
Recognition	0.5	1.1
Initiating brake application	1.24	2.34

Empirically, reaction time seems to fit a lognormal distribution



Recall the following facts about the lognormal distribution:

- If T is lognormal, $Z = \log T$ is normal (T is the exponentiation of a normal random variable)
- Thus, $T > 0$ and has a longer tail than the normal distribution.
- T has the following pdf:

$$f_T(t) = \frac{1}{\sqrt{2\pi}} \exp\left[\left(\frac{\log t - \lambda}{\xi}\right)\right]$$

  where λ and ξ are the mean and standard deviation of X (not T)
- T has the cdf $F_T(t) = \Phi((\log t - \lambda)/\xi)$ where Φ is the standard normal cdf.
- If μ and σ are the mean and standard deviation reaction time, then $\xi^2 = \log(1 + \sigma^2/\mu^2)$ and $\lambda = \log(\mu/(1 + \sigma^2/\mu^2))$.

A number of experiments have been conducted to measure reaction time.

- Johansson and Rumar (1971) stopped drivers and asked them to tap their breaks if they heard a horn.
- Fambro et al. (1994) used a closed course, where a (breakaway) barrier would randomly spring up in front of drivers.
- Fambro et al. (1994) used drivers' own vehicles and rolled barrels in front of them as a surprise.

What are some of the differences between these experiments?

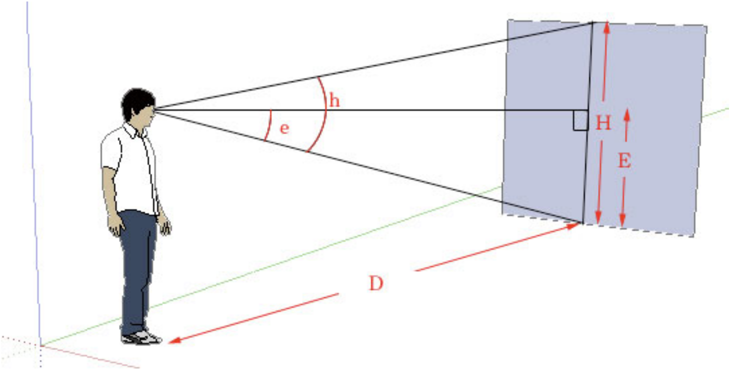
Some findings:

- Johansson and Rumar found a mean RT of 0.75 s (median 0.84 s, 95th percentile 1.27 s, 99th 1.71 s)
- With the breakaway barriers in a test vehicle, 22 out of 26 drivers braked, with a mean RT of 0.82 s
- With the breakaway barriers in drivers' own vehicles, 9 of 12 braked, with a mean RT of 1.08 s
- With the barrels, the mean RT was 1.10 s
- ...also, one driver (out of 12) apparently didn't notice or care and made no steering or braking maneuver.

PERCEPTION

A brief primer on vision...

Humans measure relative speed and distance by observing changes in the *visual angle* an object subtends.



From geometry, the visual angle θ is related to the size of an object S and its distance D by

$$\tan\left(\frac{\theta}{2}\right) = \frac{S}{2D}$$

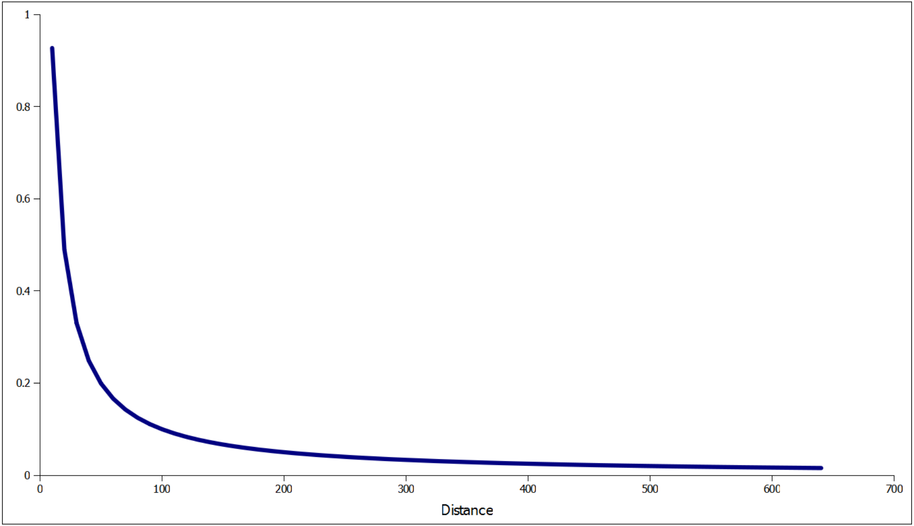
Calculating derivatives with respect to D, we have

$$\frac{d\theta}{dD} = -\frac{S}{D^2 + S^2/4} = O(1/D^2)$$

and

$$\frac{d^2\theta}{dD^2} = -\frac{2SD}{(D^2 + S^2/4)^2} = O(1/D^3)$$

So, the relative rate of change in $d\theta/dD$ is roughly proportional to $1/D$ (itself proportional to the "time of impact").


1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
700
Distance

When you are approaching a far-away object, its apparent size grows nearly linearly.

When the object becomes closer, its growth starts increasing at a faster and faster rate. This is called *looming*.

This is the brain's heuristic for detecting imminent collisions; some research indicates humans have built-in looming detectors.

Further, humans are quite bad at judging whether or not an object is accelerating; this typically requires 10-15 seconds of observation.

Changes in distance of roughly 12 percent become noticeable.

So what?

These observations suggest how car-following models should be built:

- They should not be based on acceleration of other vehicles, which humans are bad at judging.
- They can be related to the distance of other vehicles...
- ...ideally to the rate of looming and “time to collision”
- They should not be sensitive to small differences in distances and other inputs.

(Presumably humans are even worse at judging higher-order derivatives of motion such as jerk, snap, crackle, and pop. These are best avoided in traffic flow models.)

DIFFERENCES AMONG DRIVERS

Gender differences

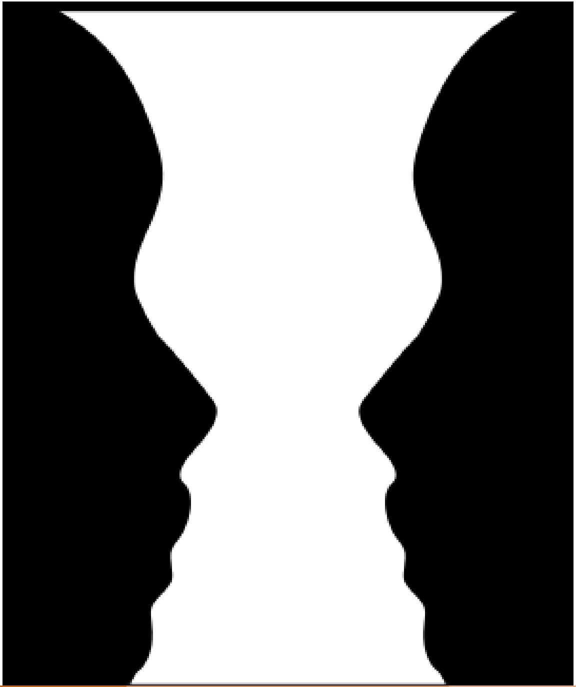
For the purpose of traffic flow, no significant differences overall.

Some interesting observations: women significantly better at color perception, men have slightly (but significantly) faster reaction time.

Age

Age affects the driving task in several ways:

- Loss of visual acuity
- Glare recovery
- Figure/ground discrimination



Age

Age affects the driving task in several ways:

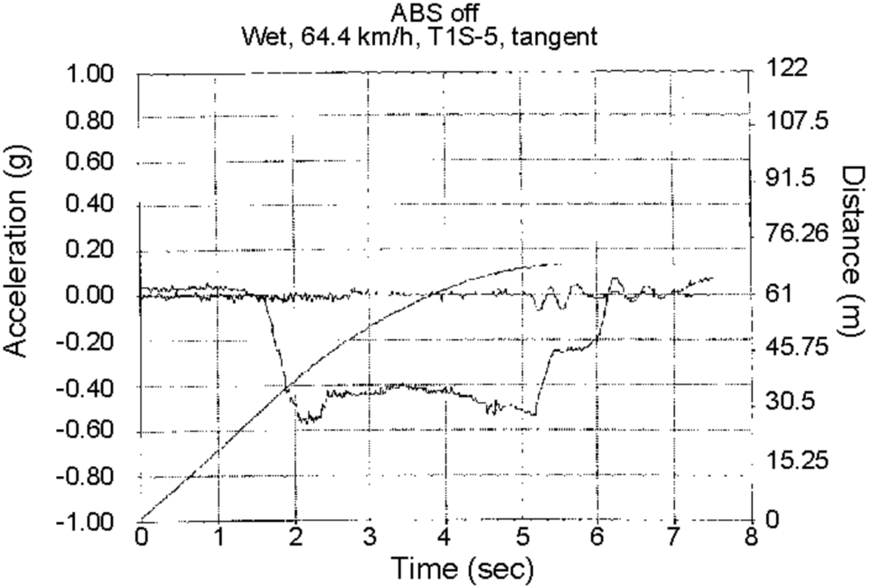
- Loss of visual acuity
- Glare recovery
- Figure/ground discrimination
- Information filtering
- Forced pacing and stress (slowing down)

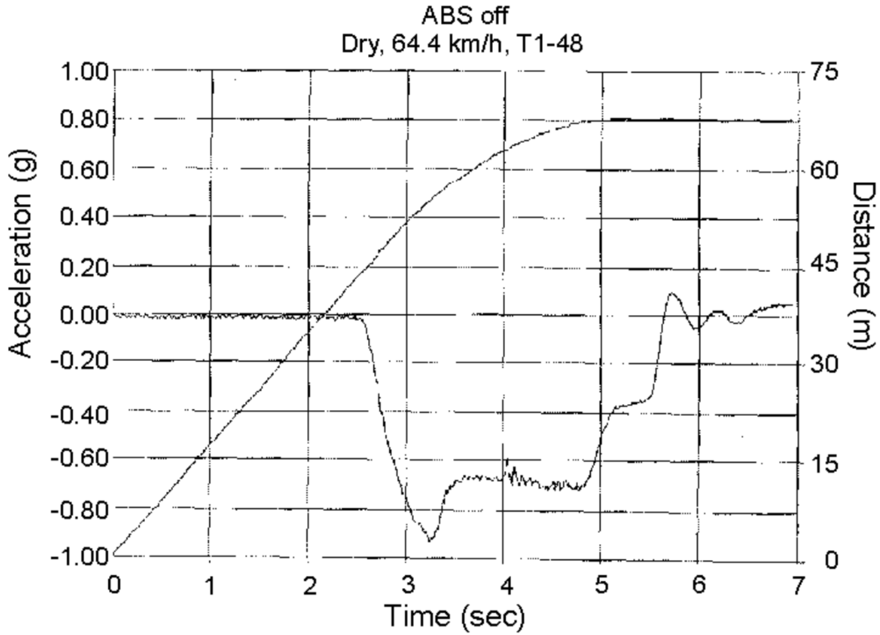
However, some of the initial research on this subject was with drivers who had not grown up driving. Some researchers believe that the performance of elderly drivers is not as reduced as initially thought.

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
Time (sec)
0
1
2
3
4
5
6
7
8


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.