Traffic Flow Theory and Simulation

V.L. Knoop

Lecture 9
Car-following: The Basics

Car-following – the basics

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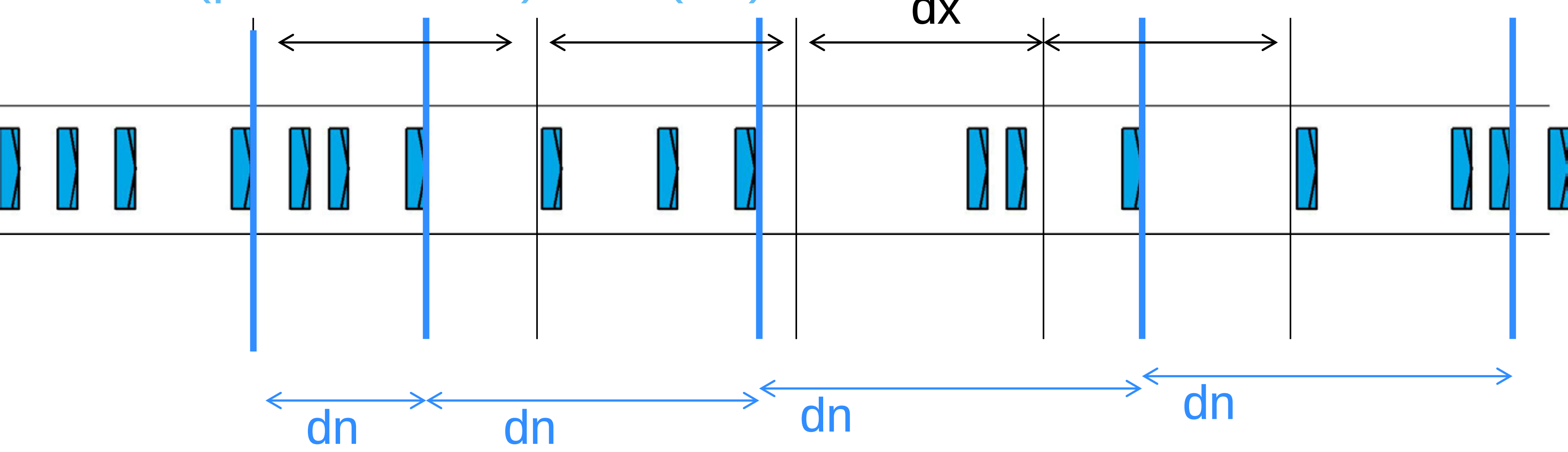
Recap Lagrangian coordinates

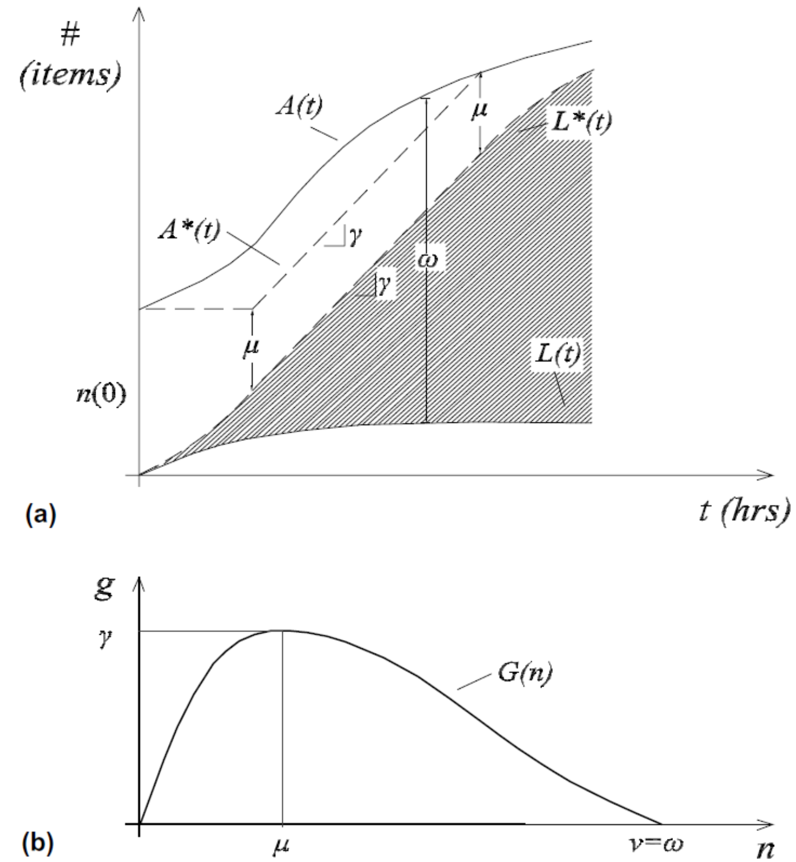
- Do not fix coordinates along the road, i.e. k=k(x,t) & q=q(x,t)
- Instead, describe the position of vehicles (platoon of dn): x=x(n,t)



Recap of Macroscopic Fundamental Diagram

- Consider ring road slide 5
- Suppose
  -an outflow governed by a MFD (fig b)
  -instantaneous density changes
  -an inflow curve A (see picture)

- Construct the cumulative curves, and calculate the delay
- How can this be improved with inflow reduction (and by how much)
- (See fig for answer, Daganzo2005)

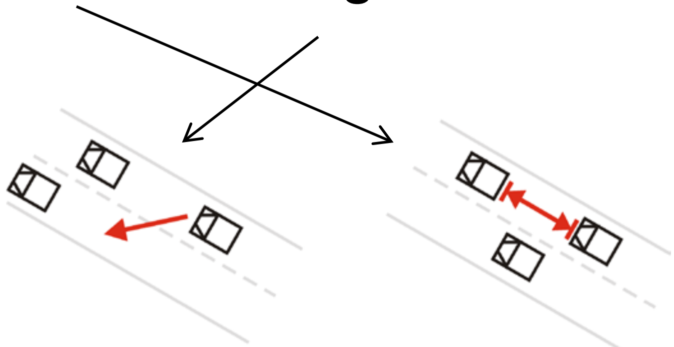


. 5. Gridlock development and control: (a) queuing diagram; (b) exit fu

Levels of description

- Area (MFD)
- Road (flows, density => e.g., shockwave theory)
- Individual vehicles – now

- Two tasks: lateral and longitudinal



Levels of the driving task

- Michon, 1985
- Strategic
  - E.g., route choice

- Tactical
  - E.g., overtaking

- Operational
  - Car operations (i.e., steering, operating throttle)

Introduction to the cf subtask

The structure of the driving task (cont' d)

Summary

	Roadway subtask	Vehicle interaction subtasks
Longitudinal	Speed choices (free speed)	Car-following
Lateral	Lane choice	Lane changing, merging, overtaking

How do drivers accelerate to their desired speed?

How do drivers interact with other (generally slower) vehicles?

Introduction to the cf subtask

Relevance of this vehicle interaction subtask

- Correct simulation tools (e.g. Fosim);
- Predictions for unknown roads
- Driver assistance systems, e.g. Adaptive Cruise Control (ACC):
  - What feels most natural?
  - What impact does it have

Rear end collision by Mark Caruso

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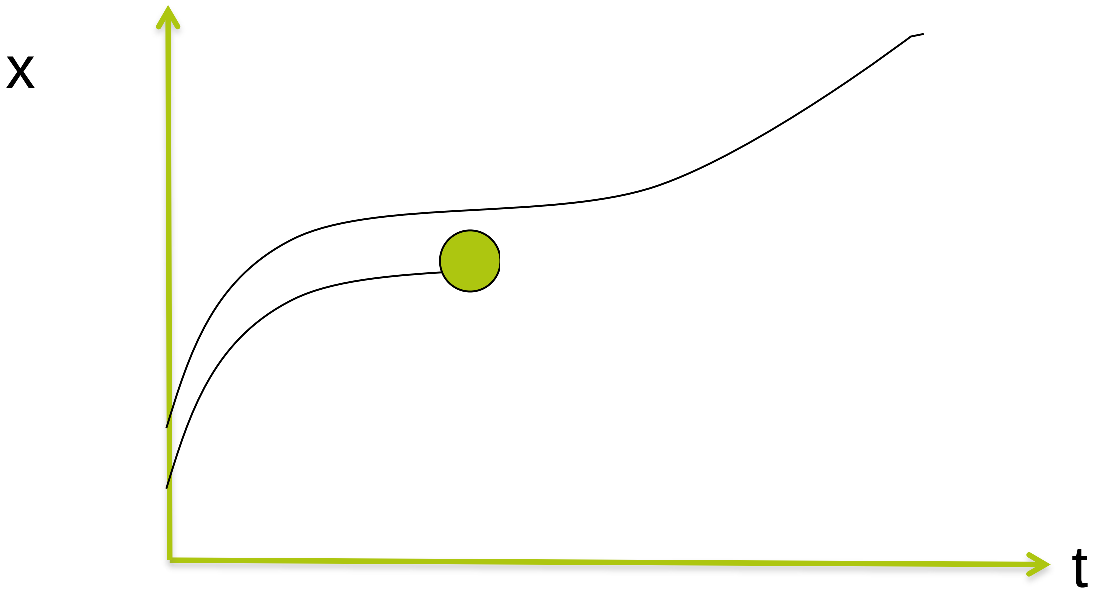
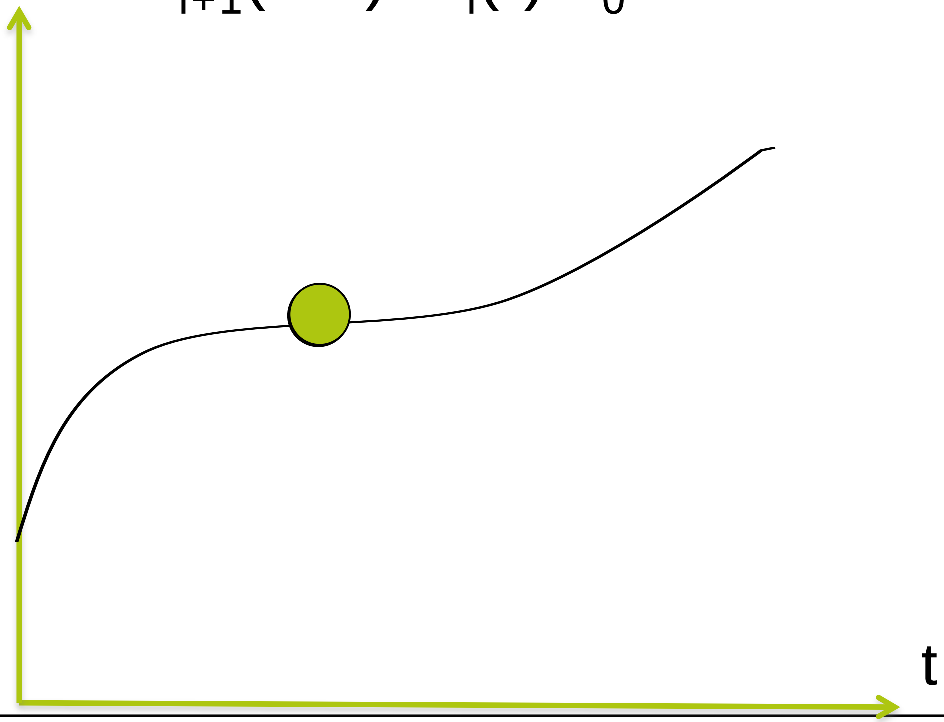
Car-following model

- Description of acceleration (or speed, or position?) of vehicle i as function of leader(s) parameters.
- a_i=... or v_i=... or x_i=...
- 5 minutes: build your own car-following model



Newell simple car-following model

1. Translate the trajectory in time
2. Translate the trajectory in space
   => $X_{i+1}(t+\tau)=x_i(t)-x_0$



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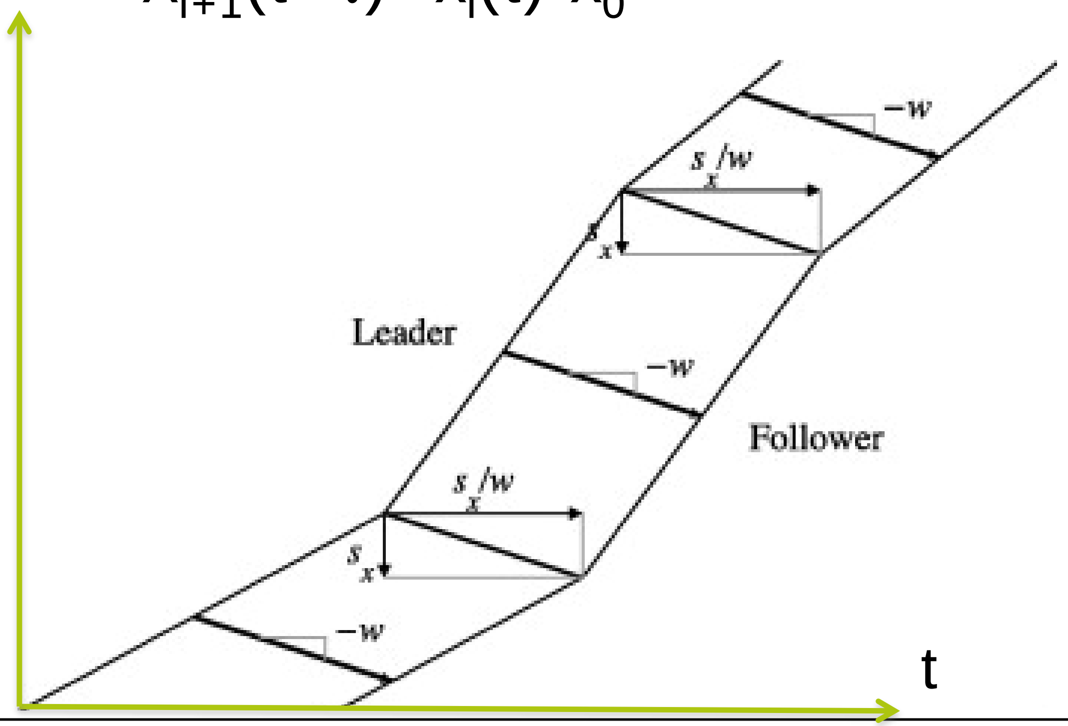

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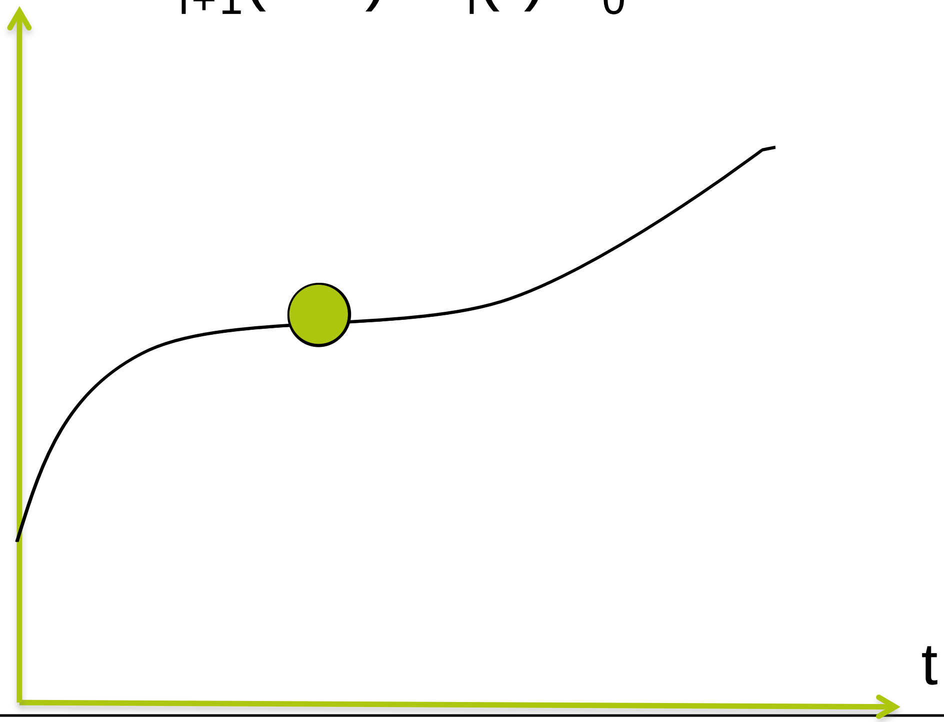
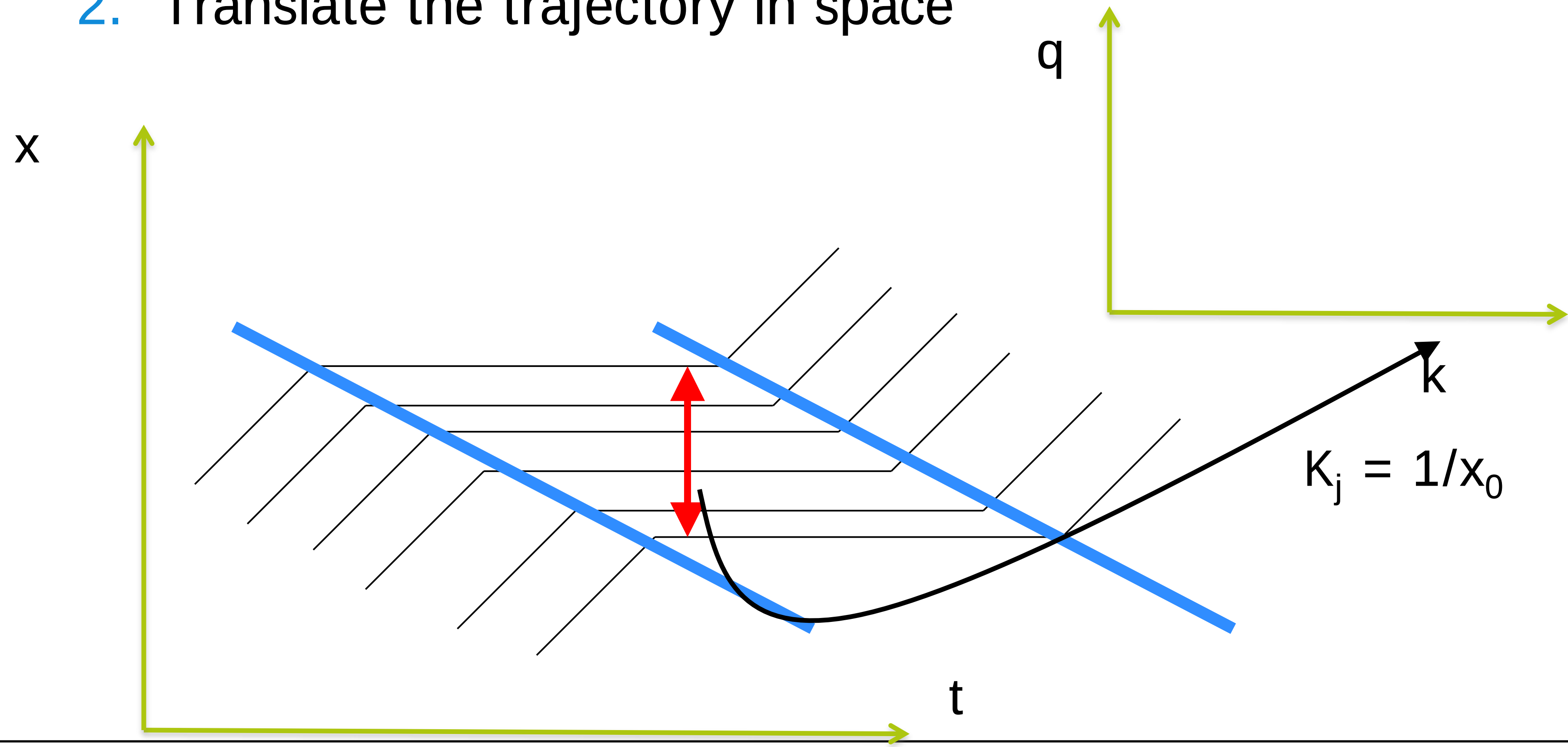
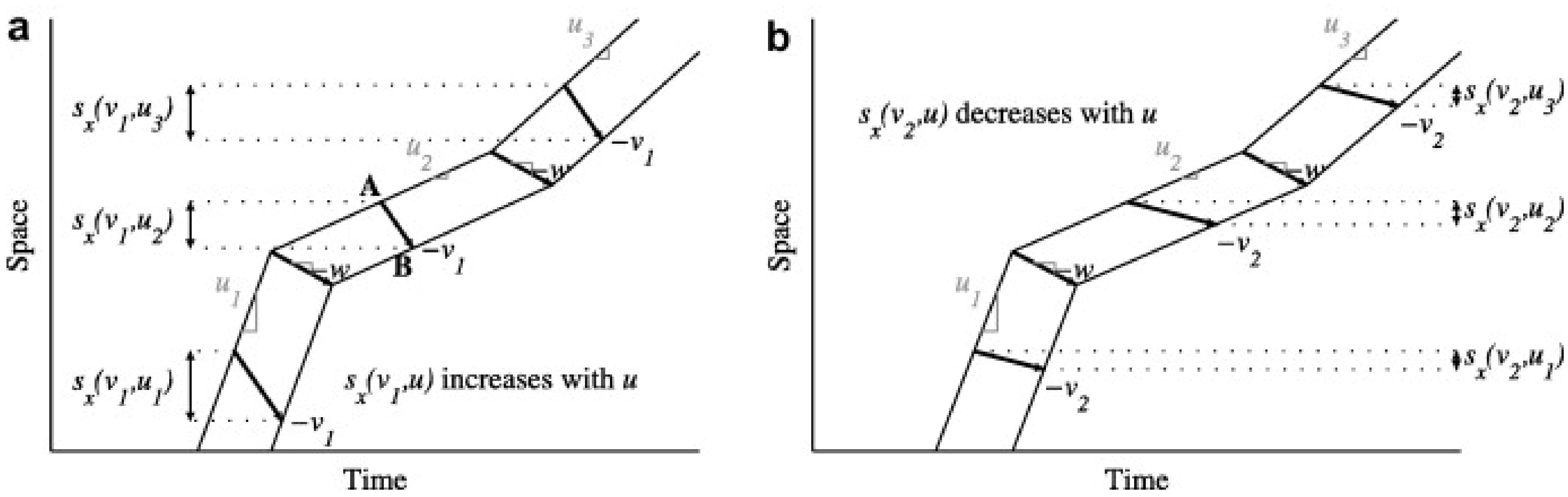


Relation microscopic-macroscopic

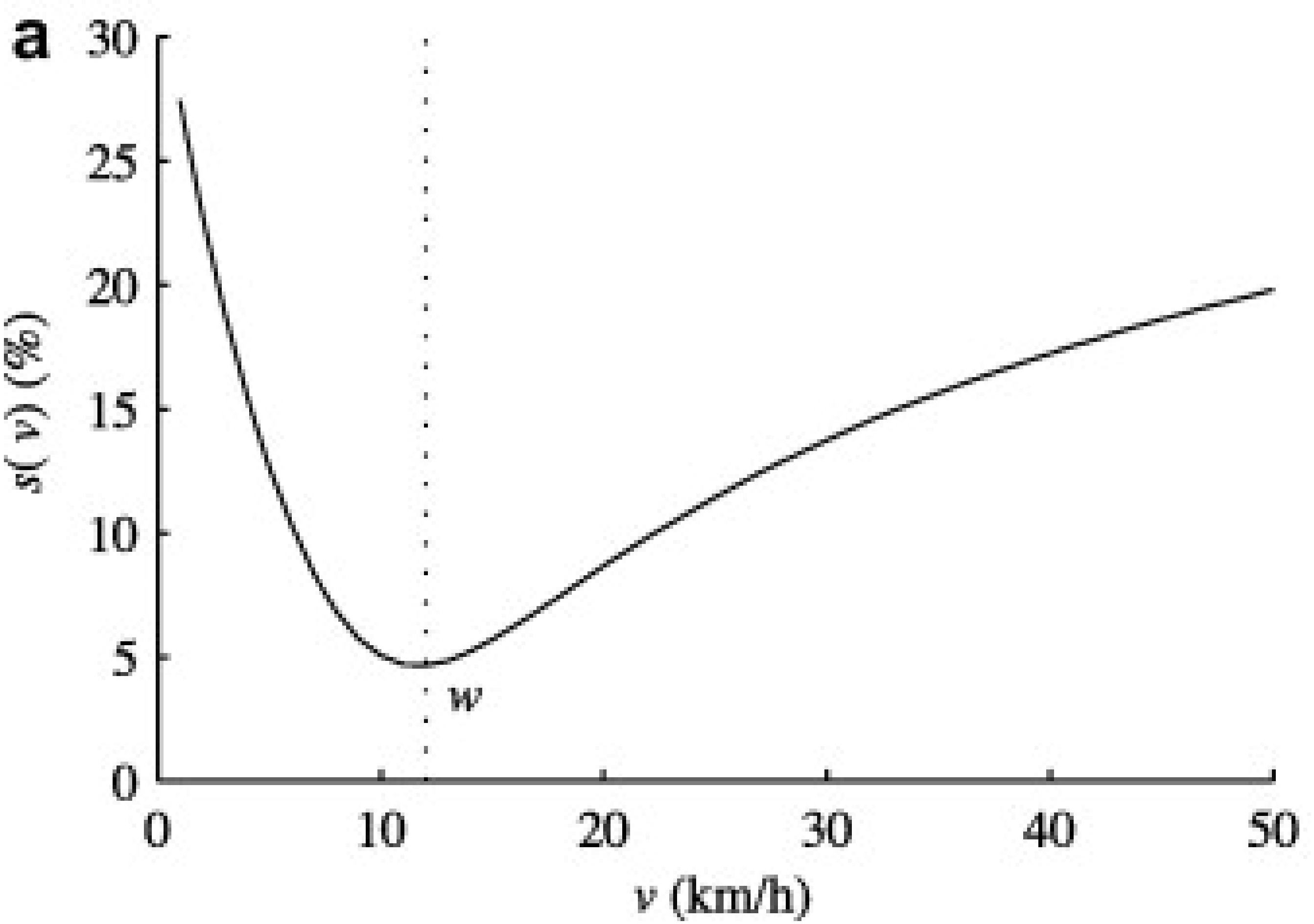
1. Translate the trajectory in time
2. Translate the trajectory in space



Finding the right value for w



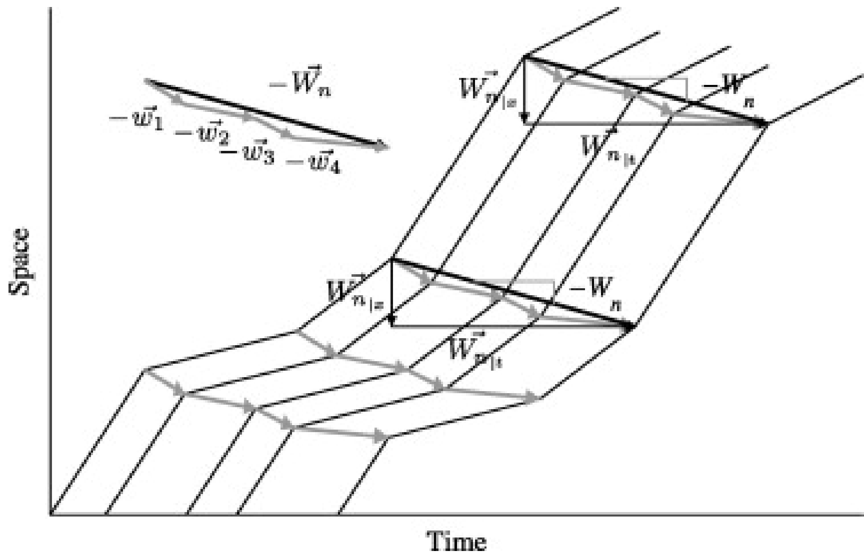
Another way to find shockwave speed



Average behaviour

- Shock wave speeds average
- 12 vehicles or more:
  no more heterogeneity

- Good approximation for choice of platoon in lagrangian coordinates



Fundamental diagram

- Newell's car-following model is equivalent with Daganzo's fundamental diagram
(in congestion = car-following mode)

Why?

Bando model

- $a = a_0 * (v^* - v)$
- $v^* = 16.8\ (\tanh(0.086(\Delta x - 25) + 0.913)$

- Relaxation towards an optimal velocity v^*

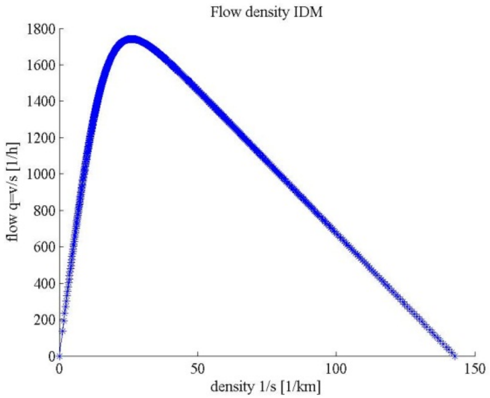
- How would you derive the Fundamental Diagram?

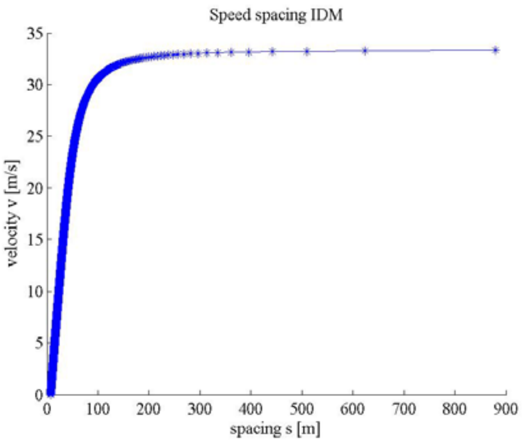
IDM model

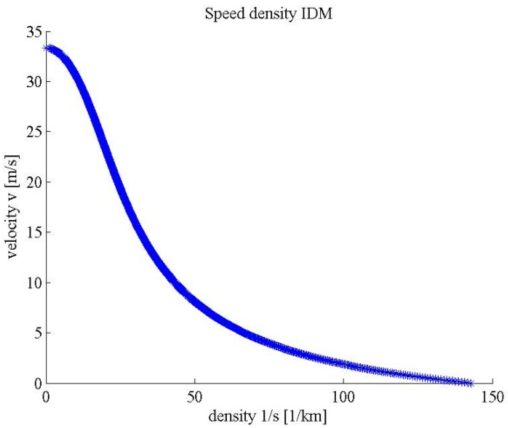
$$\dot{v}_\alpha = \frac{\mathrm{d}v_\alpha}{\mathrm{d}t} = a\left(1 - \left(\frac{v_\alpha}{v_0}\right)^\delta - \left(\frac{s^*(v_\alpha, \Delta v_\alpha)}{s_\alpha}\right)^2\right)$$

$$\text{with } s^*(v_\alpha, \Delta v_\alpha) = s_0 + v_\alpha T + \frac{v_\alpha \Delta v_\alpha}{2\sqrt{a\,b}}$$

Fundamental Diagrams







Learning goals

- Now you can:
  - Comment on use of microscopic simulation
  - Switch views (microscopic and macroscopic) for a model

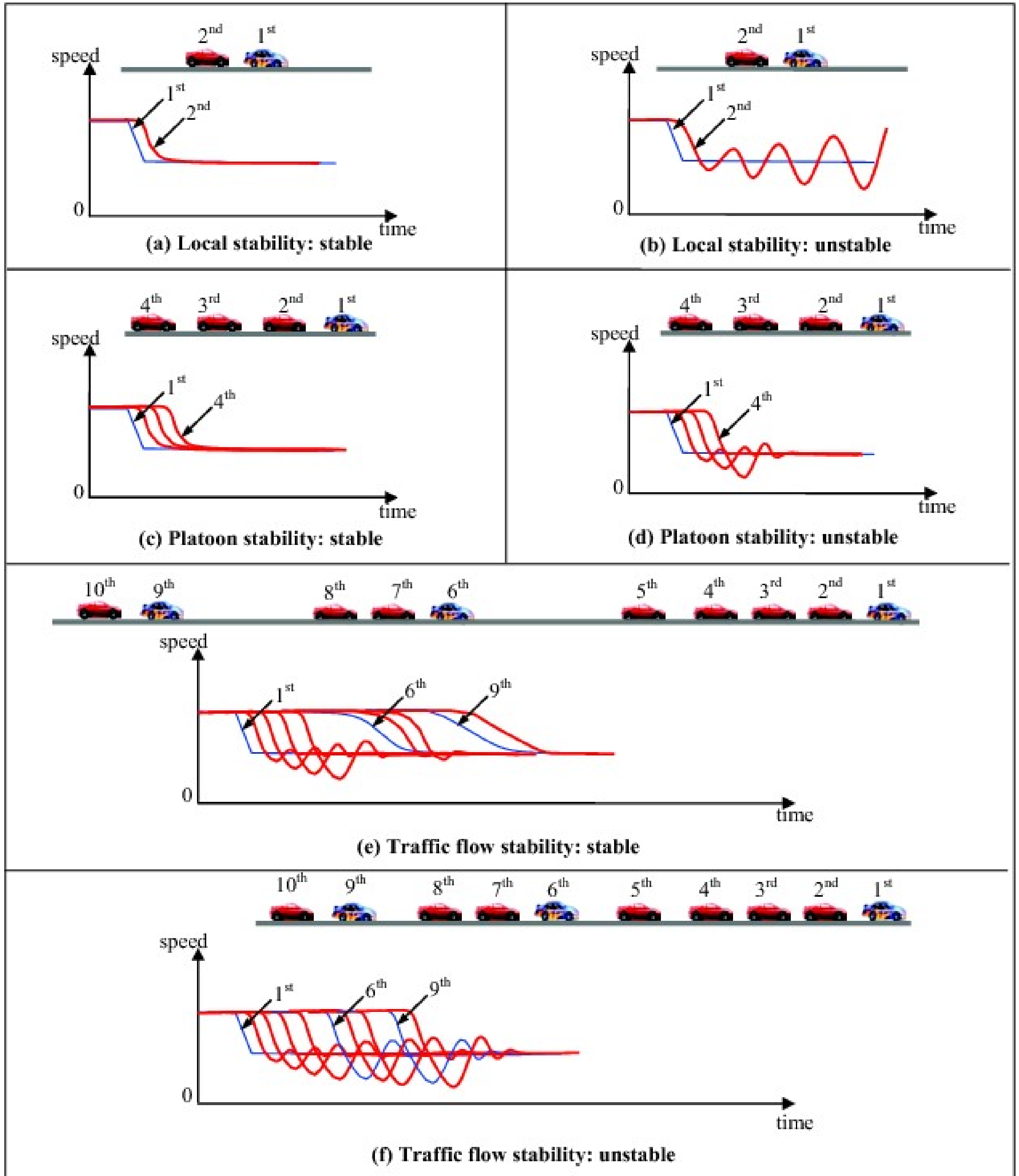
STABILITY

Local stability
(1 follower instable)

Platoon/asymptotic stability

Traffic flow stability /

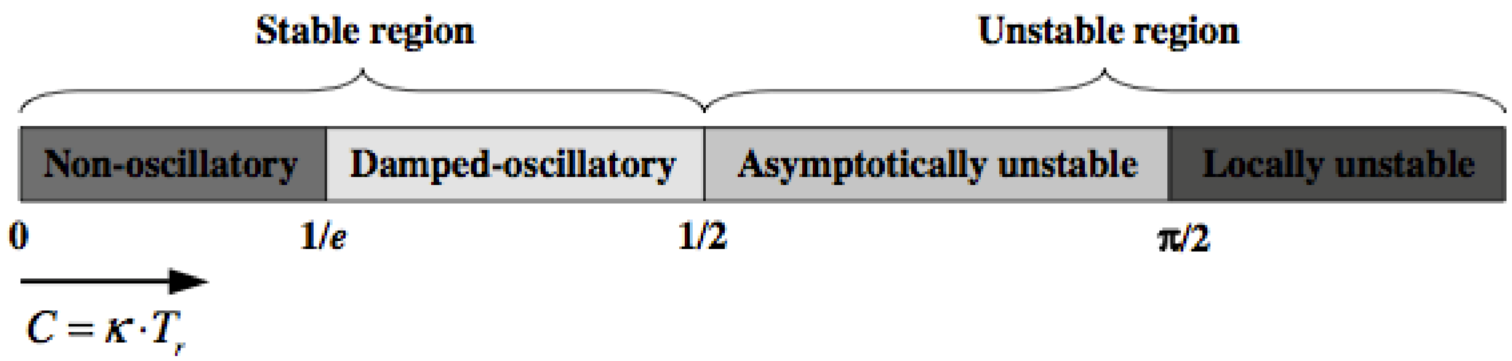
Traffic flow instability



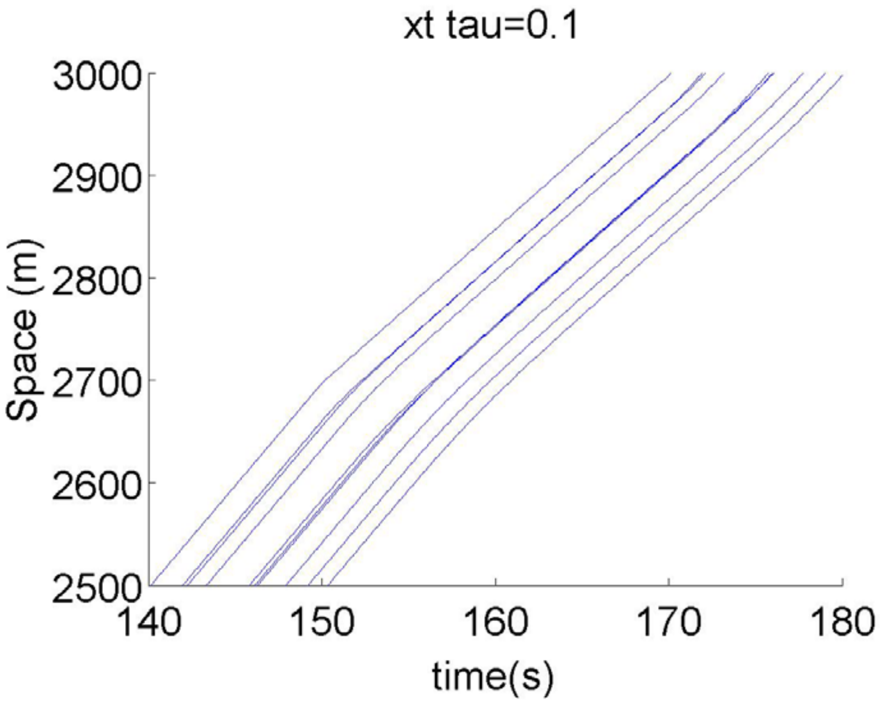
Stability analysis

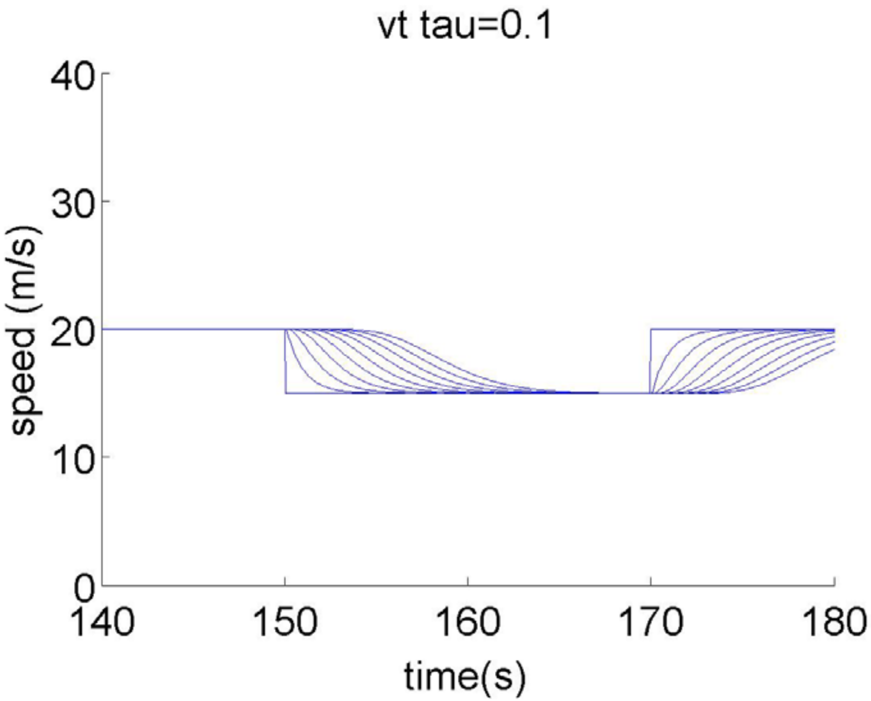
- Example model:

- $A(t+\tau)=kappa(v_{i-1}-v_i)$
- With increasing kappa, stability:
  - A: increases
  - B: decreases
  - C: is the same

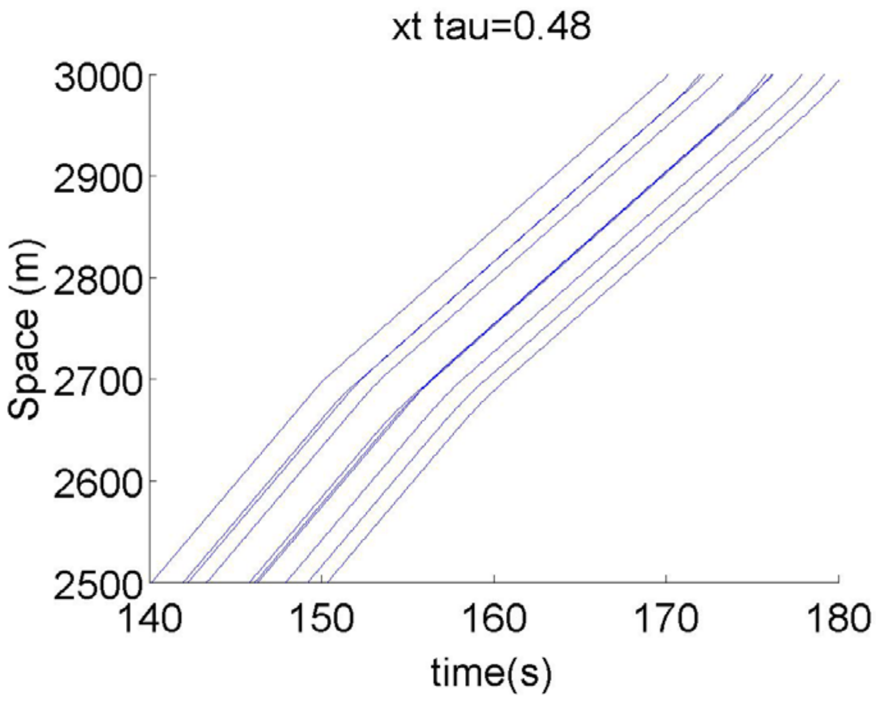


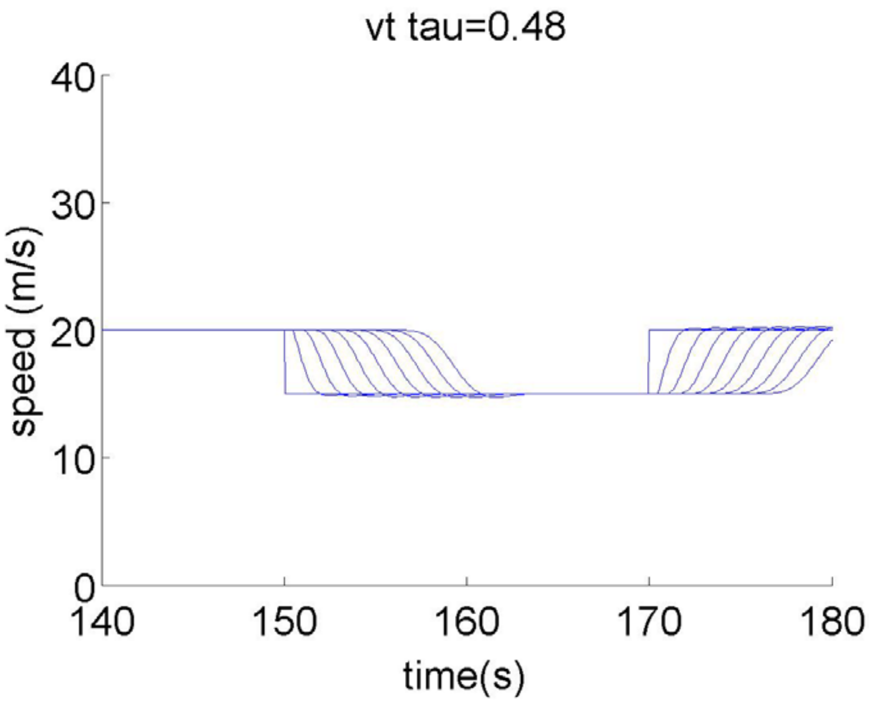
Non oscillatory



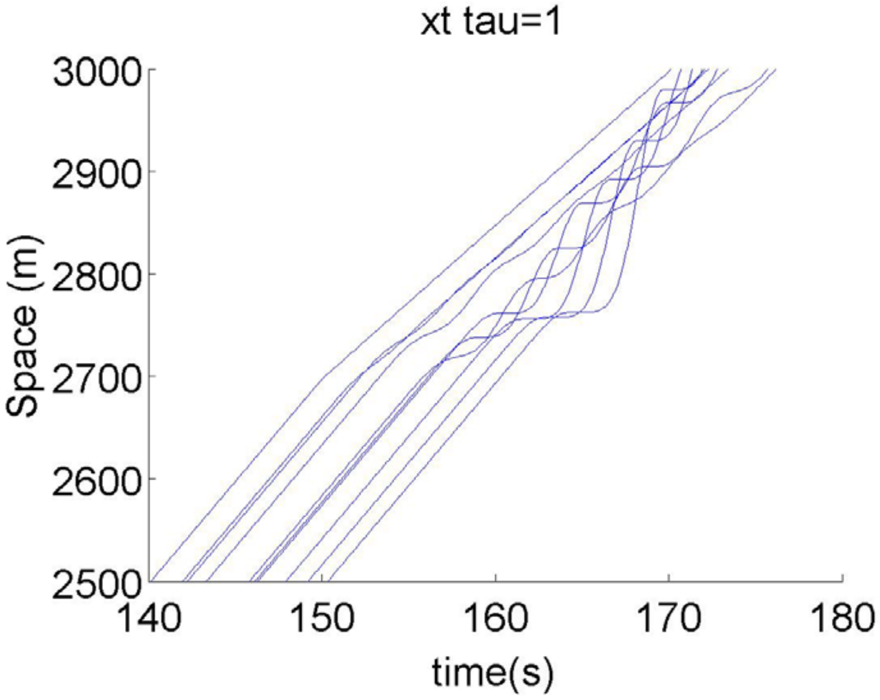


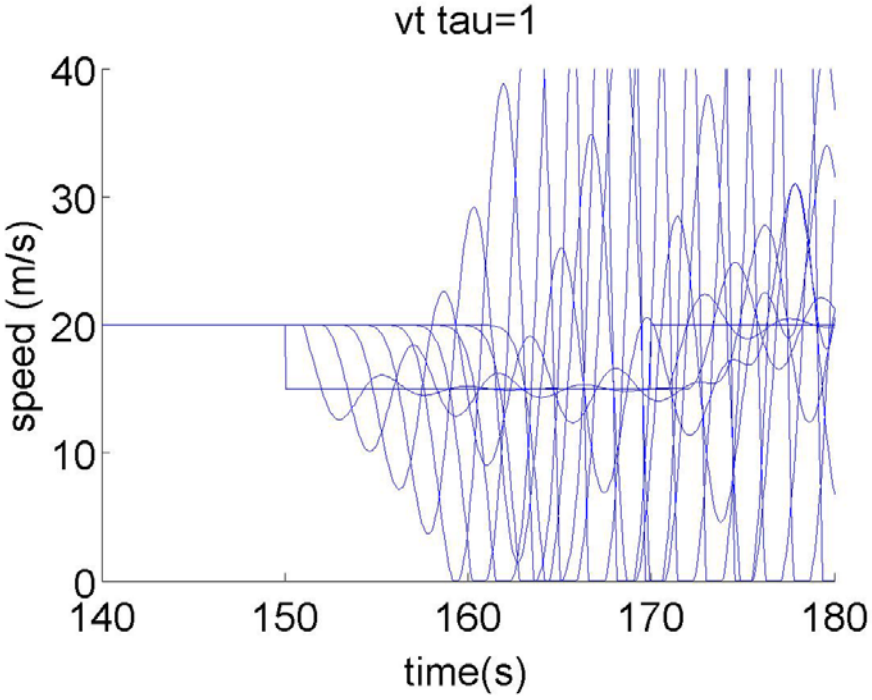
Damped oscillatory



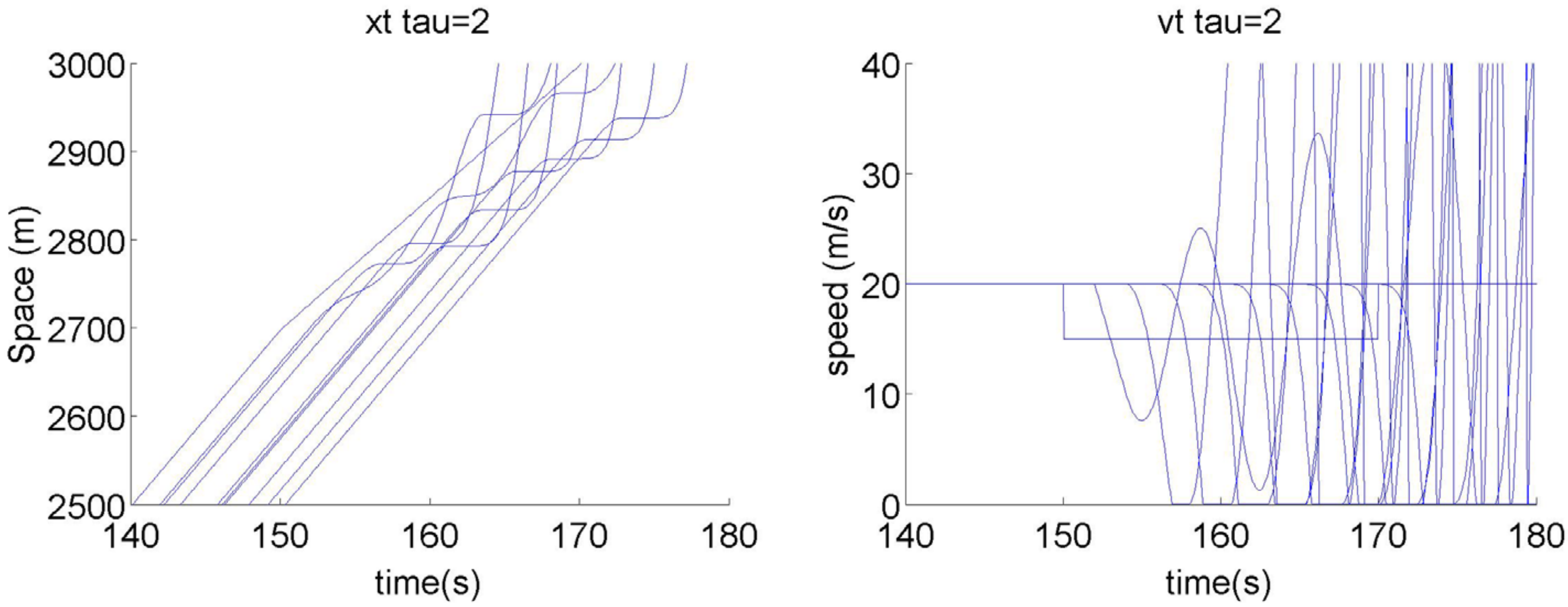


Asymptotically instable





Locally unstable



Multiple leaders

- Instead of a=a(Xleader,Xfollower)
  => a=a(Xleaders, Xfollowers)
  in which X={pos, speed, acceleration, ...)

- How does this influence stability
  A – improves (more stable)
  B – worsens (less stable)
  C – no influence

Design a multi-leader model

- How would you design a multi-leader model?
  Inspired by IDM or Newell...

$$\dot{v}_\alpha = \frac{\mathrm{d}v_\alpha}{\mathrm{d}t} = a\left(1 - \left(\frac{v_\alpha}{v_0}\right)^\delta - \left(\frac{s^*(v_\alpha, \Delta v_\alpha)}{s_\alpha}\right)^2\right)$$

$$\text{with } s^*(v_\alpha, \Delta v_\alpha) = s_0 + v_\alpha T + \frac{v_\alpha \Delta v_\alpha}{2\sqrt{a\,b}}$$

Approaches for multi-leader models

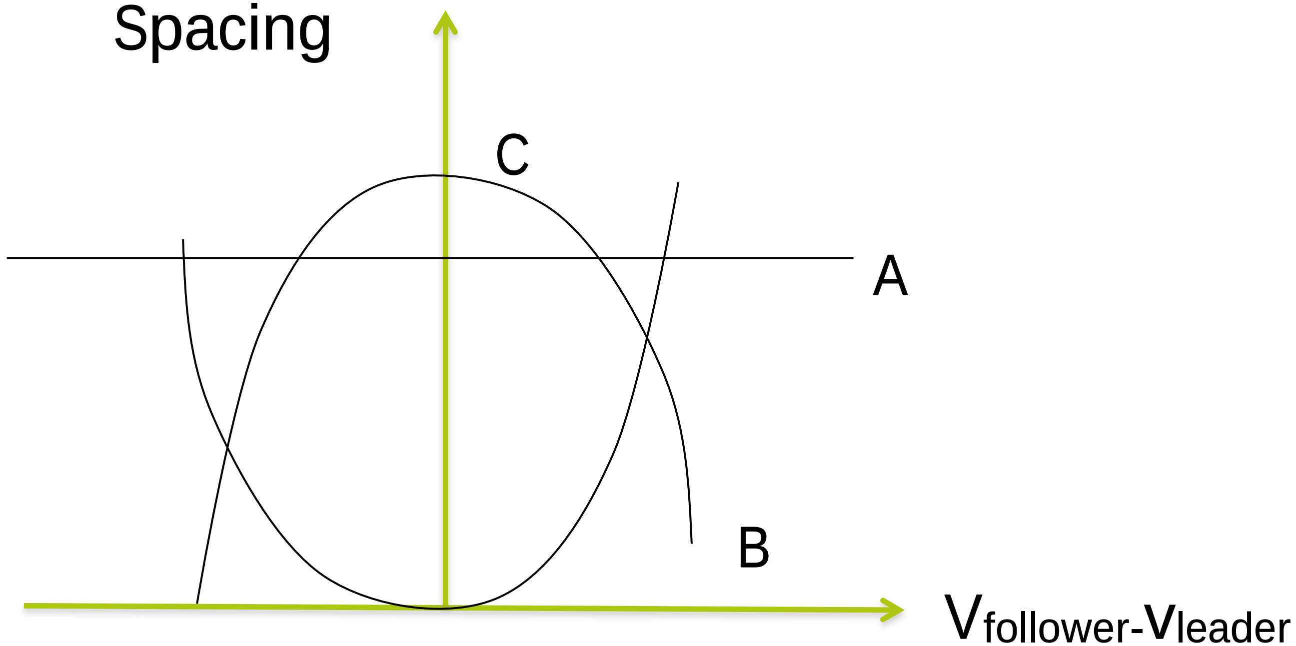
- (Your models?)

Action point models

- The assumption of continous and perfect operation is unrealistic
- Why?

Perception thresholds

- People do not notice small speed differences at large distances
- What are observation thresholds?



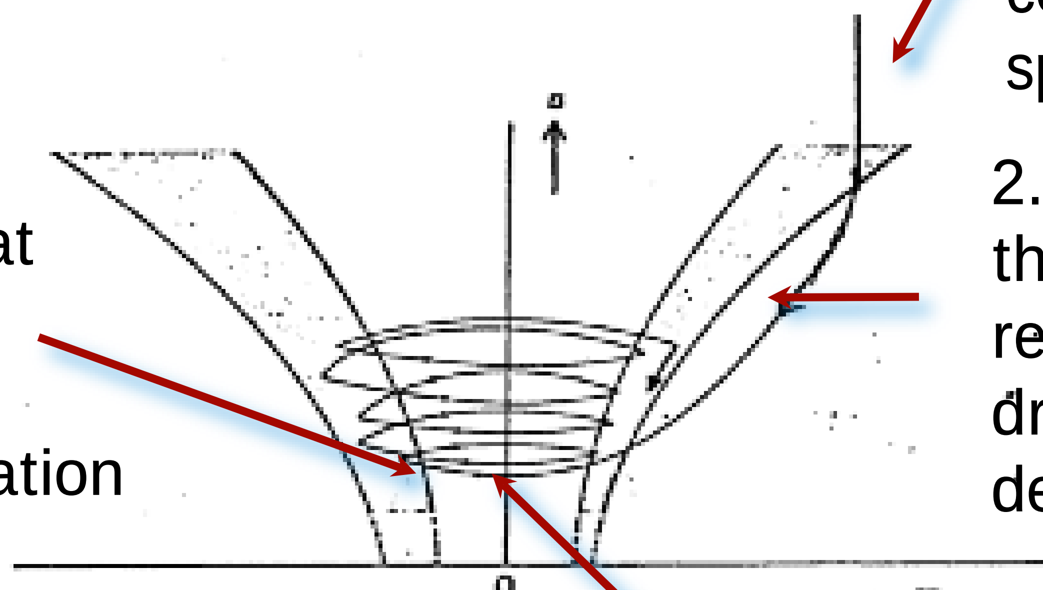
Principle by Wiedeman

1. A follower with a speed larger than the leader approaches with constant relative speed

2. When the threshold is reached, the driver decelerates

3. Deceleration until Δv=0

4. No notice that driver over-deceleraties, so relative acceleration



$V_{follower} < V_{leader}$

$V_{follower} > V_{leader}$

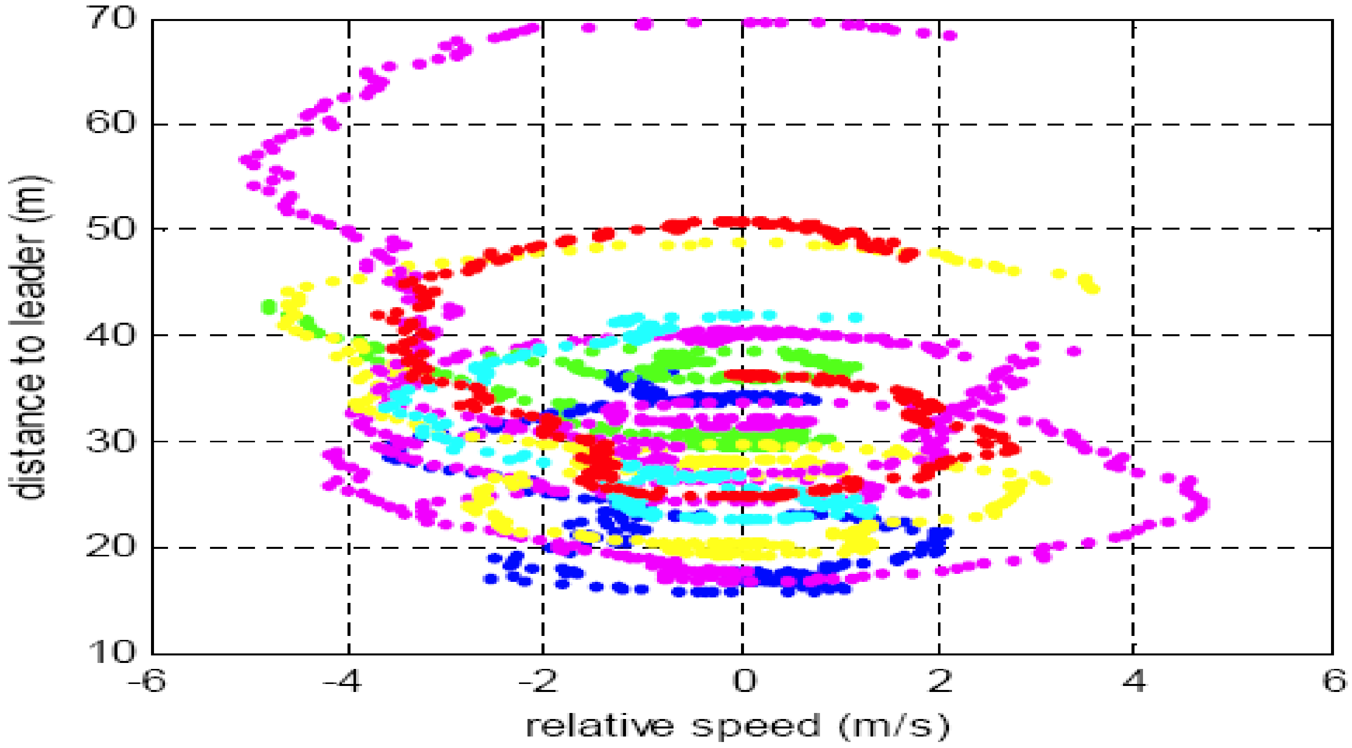
Wiedeman: a second thought

- Wiedeman principle is not a car-following model

  => why not

The basics of car-following models

Action point models (cont'd)



Car-following and the basics
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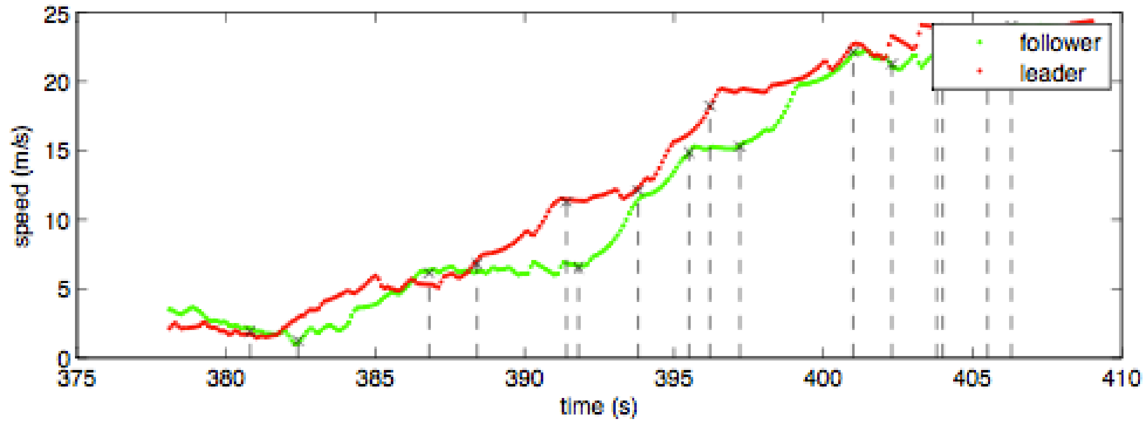
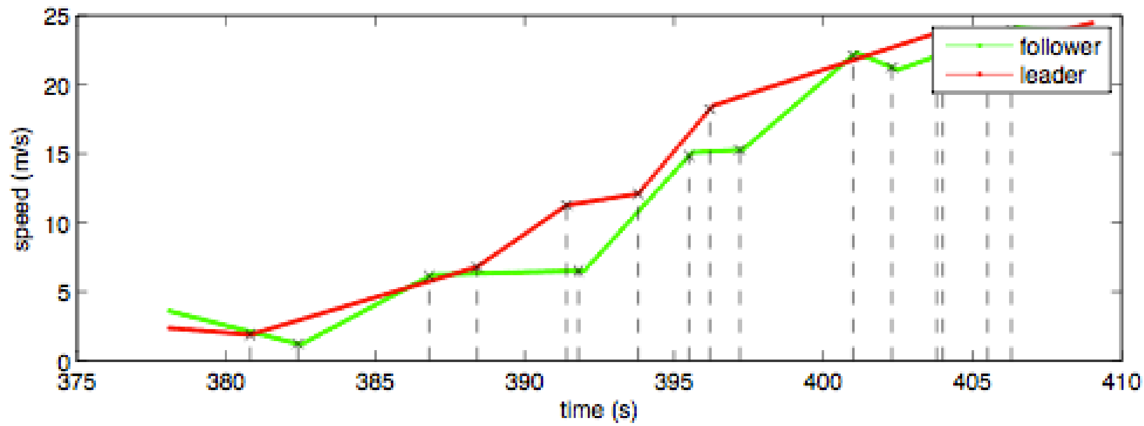
The basics of car-following models

Action point models (cont’d)

- Action points not so bad compared with real-life data
- Where are the action points located?





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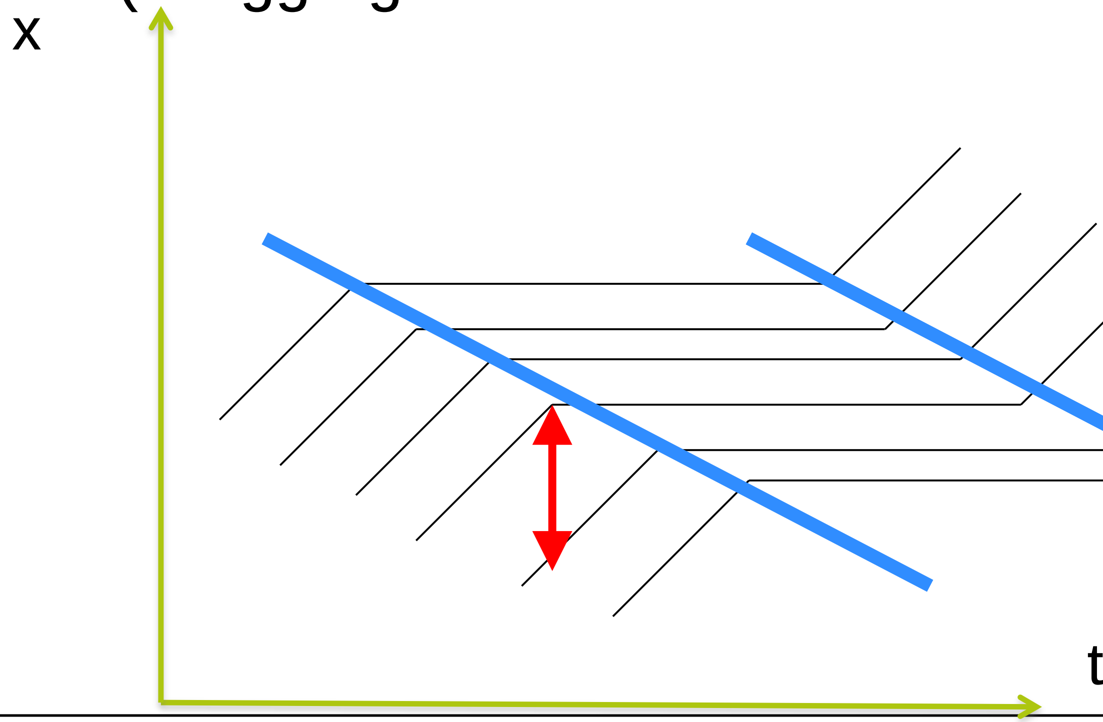
The basics of car-following models

Action point models (cont'd)

Further problems

- Evaluation points:
  For behavioral results: analysis along wave speeds (~ aggregation method in lecture 6) => why?



CELLULAR AUTOMATA MODELS

Cellular automata models

- roadways are divided into small cells with a constant length of Δx ~5-10 m
- these cells are either occupied by one vehicle or not;
- Speeds are also discretised:
  v=i*dx/dt, with i=0, 1, 2 ...

- Small Δx might improve accuracy, but speed advantage lost

Cellular automata models

- Updating of the vehicle's dynamics is achieved through the following rules:
  - Acceleration: if a vehicle has not yet reached his maximum speed v_{max}, and if the lead vehicle is more than one cell away: v=v+1
  - Braking: if a vehicle driving with a speed v has a headway of Δj with Δj<v then the speed of the vehicle is reduced to (Δj-1);
- Randomisation;

Learning goals

- Now, you can...

1. describe what a car-following model is
2. Calculate the following behaviour for the Newell (no equations given)
3. Calculate the folllowing behaviour for IDM and other models given in document on blackboard (equations will be given)
4. Comment on stability (local, platoon, traffic)
5. Derive the fundamental diagram from a car-following equation
6. Describe the principle of cellular automata
7. Describe the Wiedeman principle