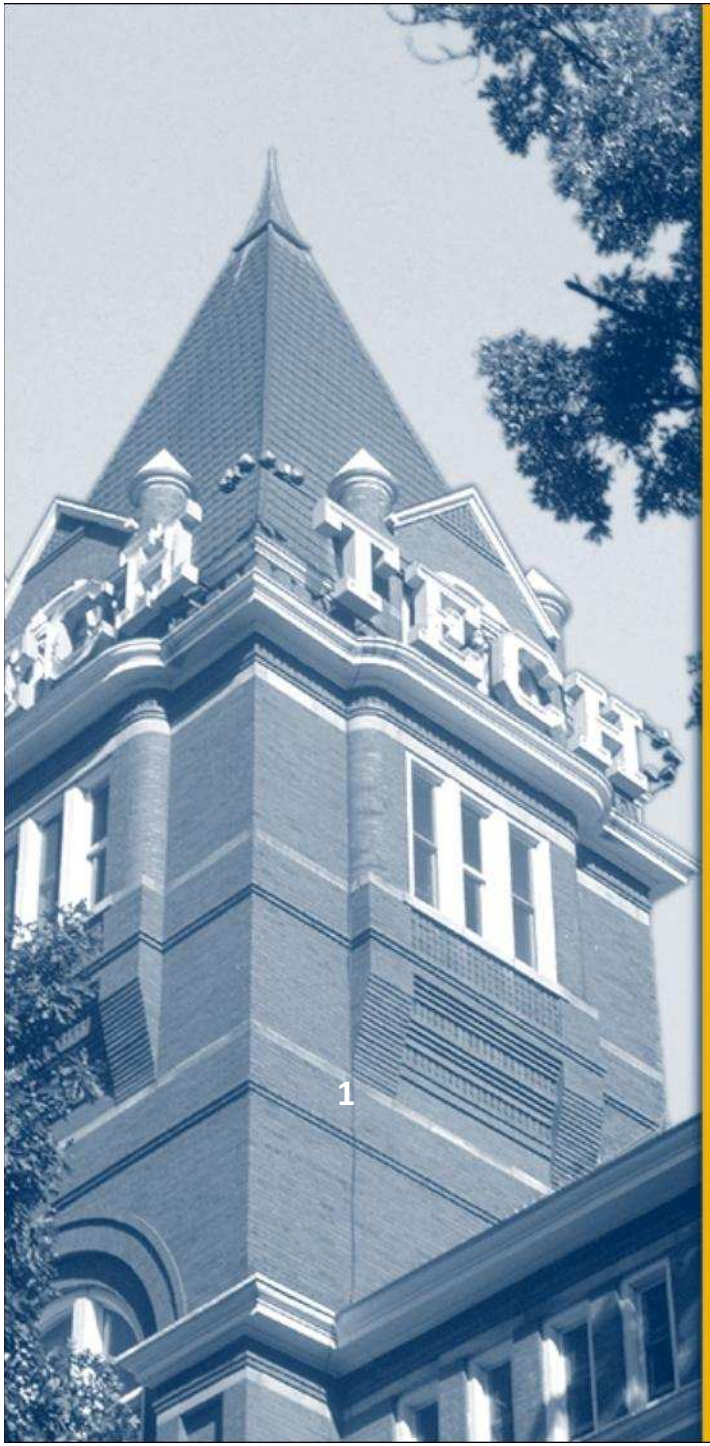


Features of oscillations when propagating through a homogenous highway segment

Danjue Chen

Georgia Institute of Technology

Outline

- Introduction
- Literature review
- L-L Model
- Measurement
- Application
- Further research

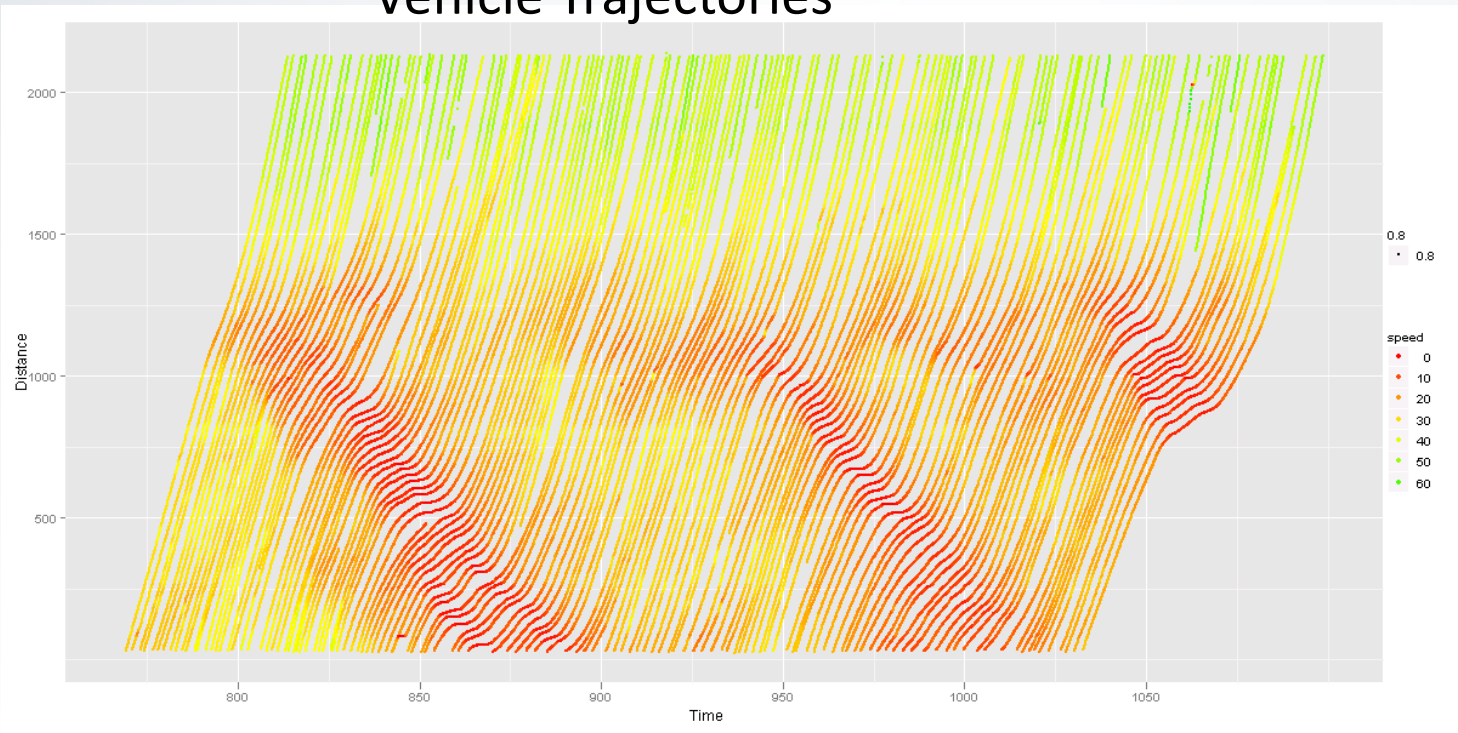
2

Introduction (1)

What's oscillation?

- Stop-and-go driving motions
- Deceleration and acceleration cycles

Vehicle Trajectories



Source: NGSIM

Introduction (2)

- A Common phenomena: oscillations occur in congested traffic.
- Problems they cause: severe congestion, reduced fuel efficiency, more emission, safety risk, etc.

- Existing models do not capture oscillation accurately.

Literature Review

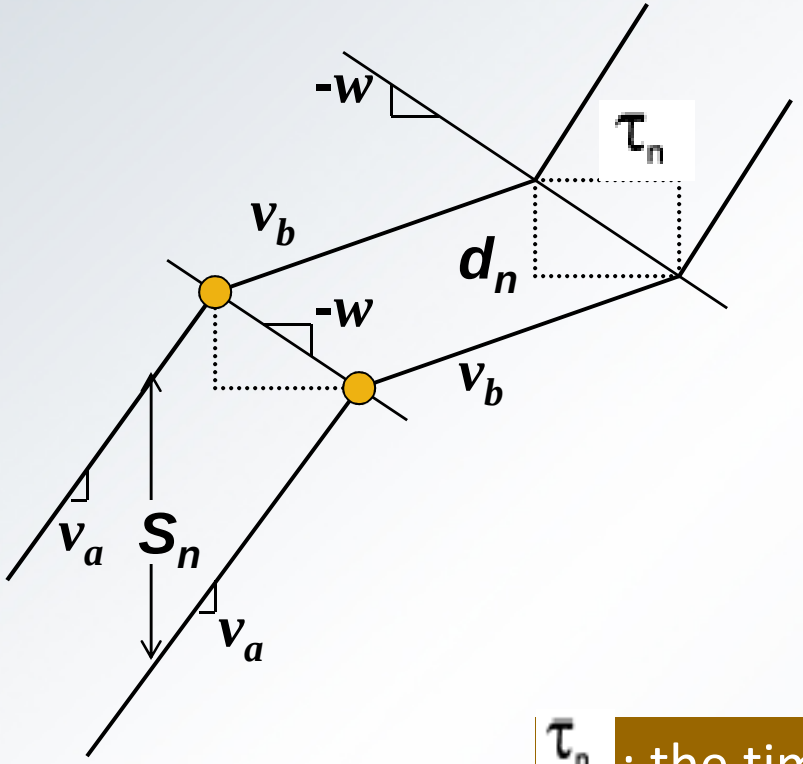
Three types of models:

- Car-following models
  - Period predicted does not match observations.
  - CF models: a few seconds
  - Observations: vary from 2~15min (Kerner & Rehborn, 1996, Mauch & Cassidy, 2002, Ahn & Cassidy, 2007, etc.)
- Fully Stochastic Models
  - Oscillations are due to a break probability (Barlovic et al., 1998, 2002)
  - Require a large number of non-physical parameters, hard to implement (Helbing and Treiber, 1998, Shvetsov & Helbing, 1999, etc).
- Human-error models
  - Oscillations might be caused by human error (Yeo and Skabardonis, 2009).
  - L-L car-following model (Laval & Leclercq, 2010)

Source: NGSIM

L-L Model

Basis: Newell's model (2002)



- Drivers try to follow their leaders' speed.
- Changes of speed spread upstream with distance d_n and time τ_n
- To switch to a new speed, a driver changes his speed upon reaching the spacing he prefers for the new speed.

τ_n: the time needed to get to the preferred spacing for a new speed. Independent of speed.

L-L Model

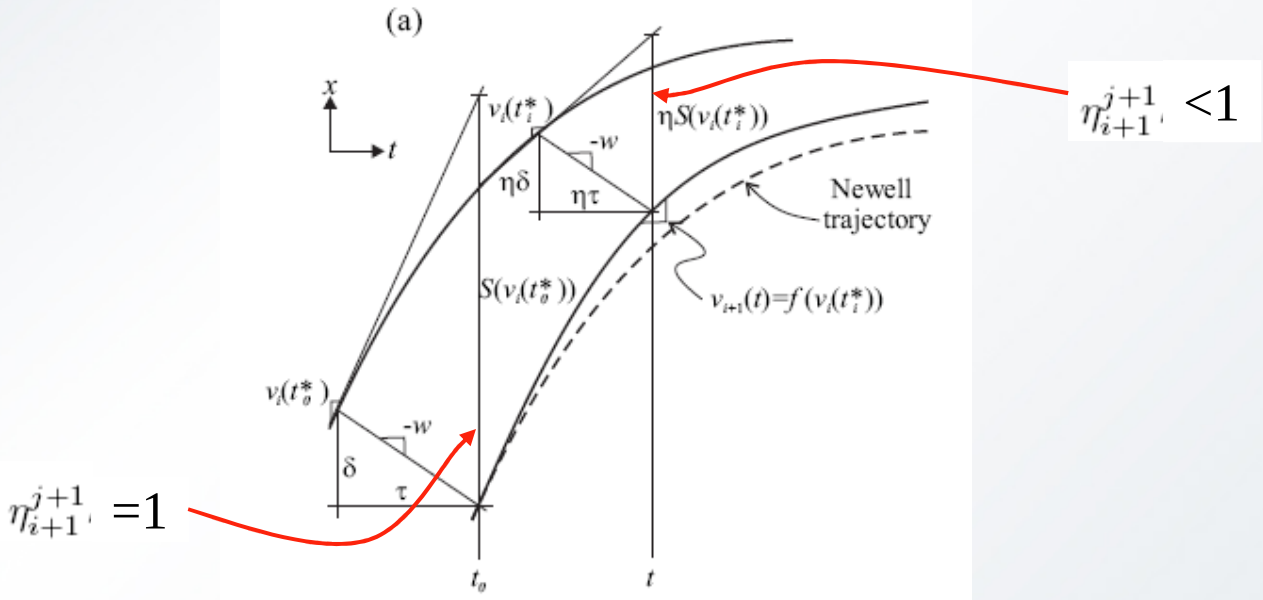
L-L Model:

Newell's CF model-Exact KWT solution

$$x_{i+1}(t) = \min\{x_{i+1}(t-\tau) + u\tau, x_i(t-\tau) - \delta\}.$$

L-L Car-following Model

$$x_{i+1}^{j+1} = \min\{\underbrace{x_{i+1}^{j} + \min\{u, v_{i+1}^{j} + a\tau\}\tau}_{\text{free-flow term}}, \underbrace{x_i^j + \eta_{i+1}^{j+1}\tau v_i^{j+1} - \eta_{i+1}^{j+1} S(v_i^{j+1})}_{\text{congested term}}\}$$



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L-L Model

L-L model:

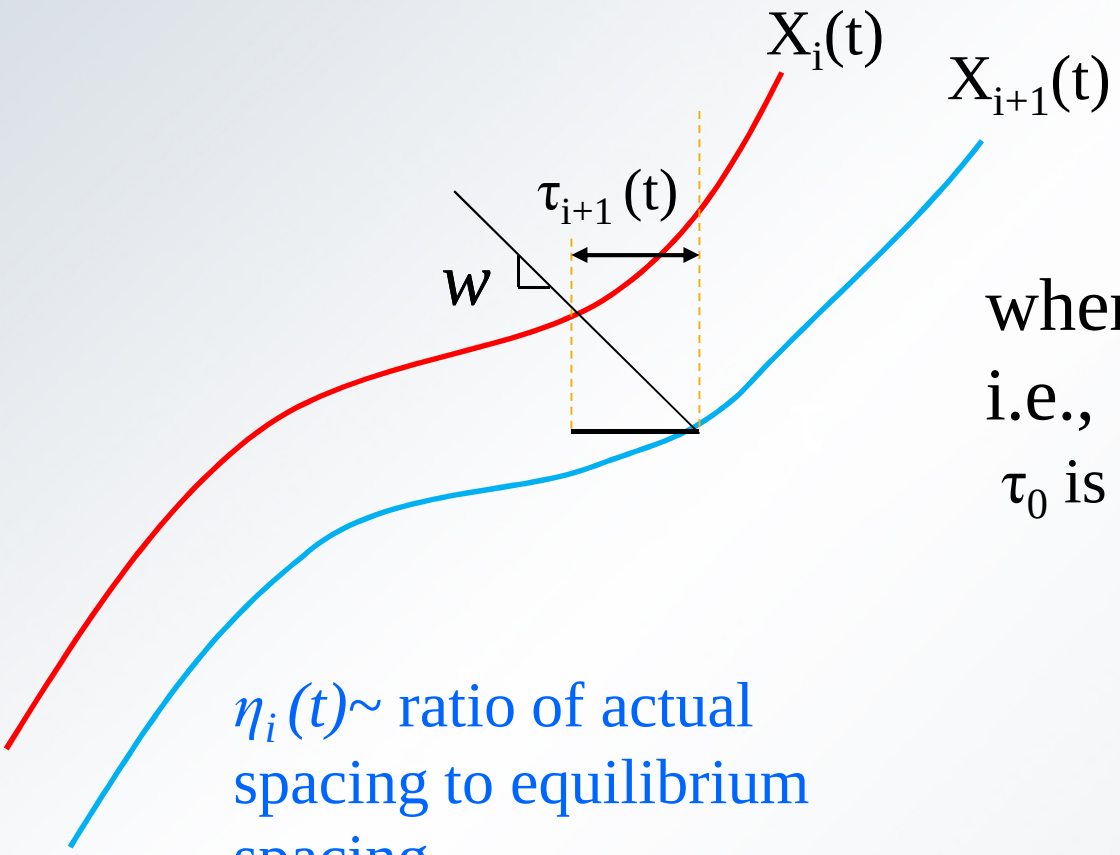
Key problems: measurement of $\eta_i(t)$

- Initial value?
- How will it change?

Source: NGSIM

Measurement

Definitions



$\eta_i(t)$~ ratio of actual spacing to equilibrium spacing

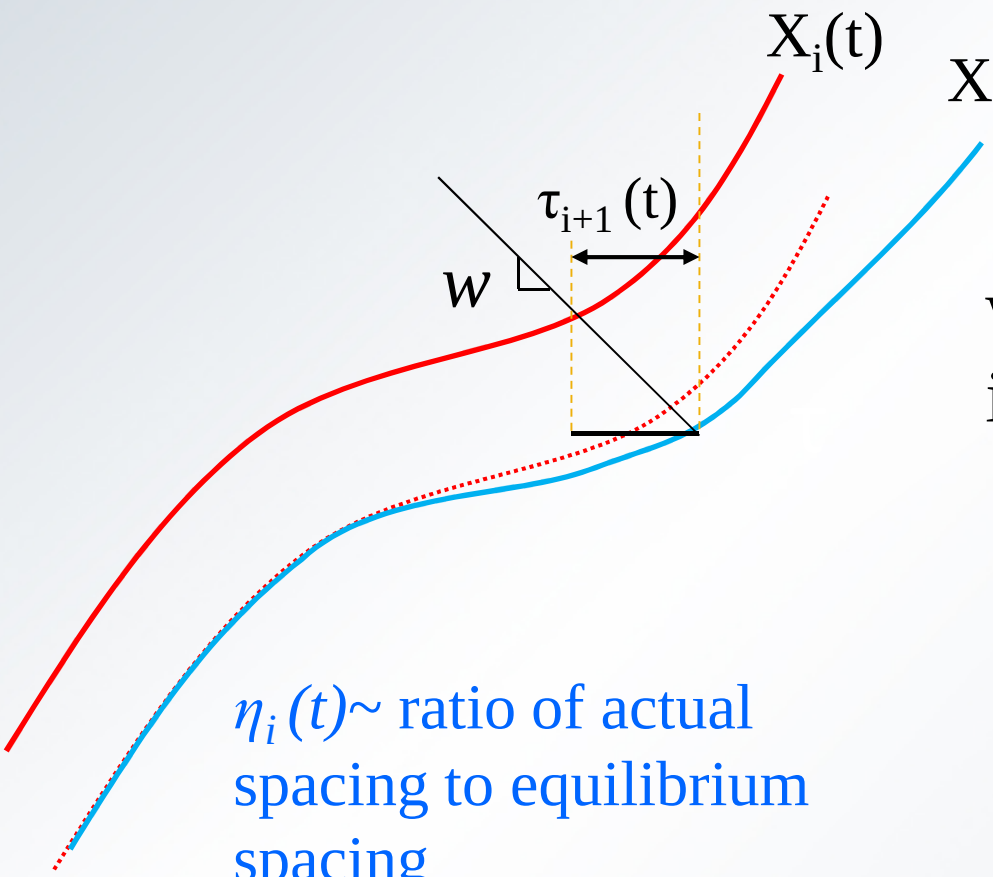
$\eta_i(t) = \tau_i(t) / \tau_0 = S_i(t) / S_0$

where τ_0 is the theoretical τ, i.e., $\tau_0 = 1/(K_j w)^{-1}$

τ_0 is set to be 1~2.1sec

Measurement

Definitions



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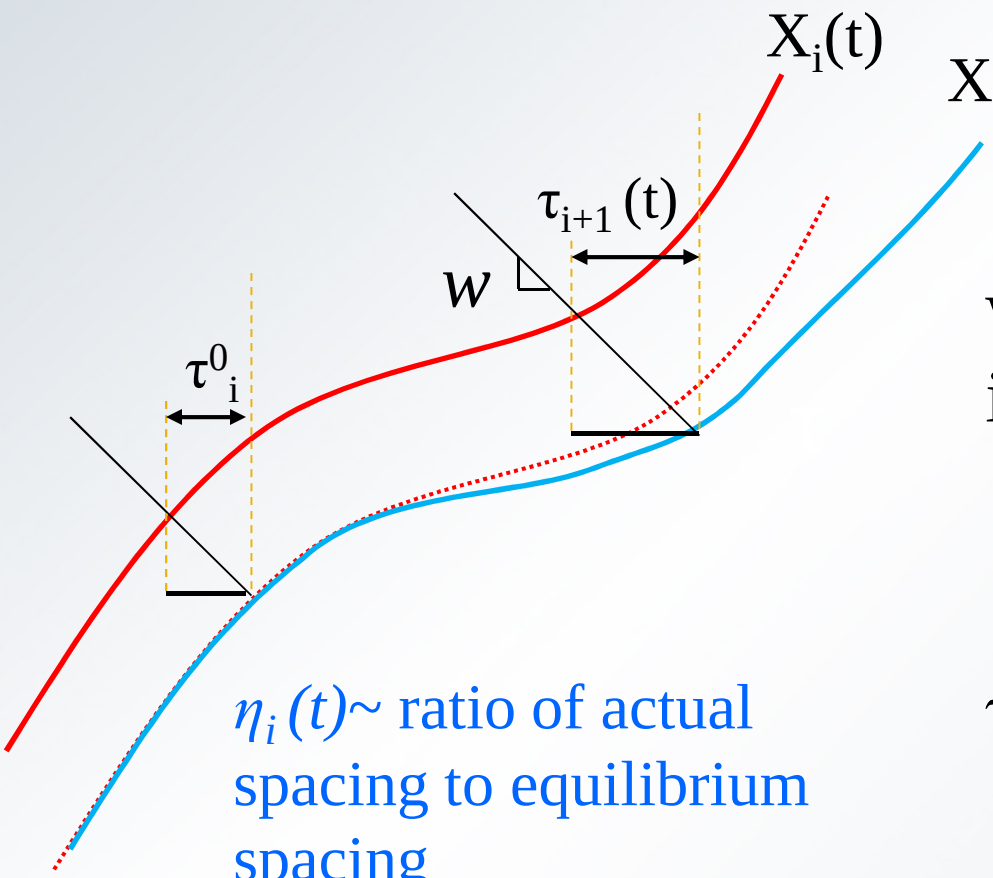
Measurement

Definitions



$\eta_i(t)$~ ratio of actual spacing to equilibrium spacing

$\eta_i(t) = \tau_i(t) / \tau_0$

where τ_0 is the theoretical τ, i.e., $\tau_0 = 1/(K_j w)^{-1}$

τ_0 is set to be 1~2.1sec

$\eta^0_i = \tau^0_i / \tau_0$

$\tau_0 = \text{mean}(\tau^0_i)$

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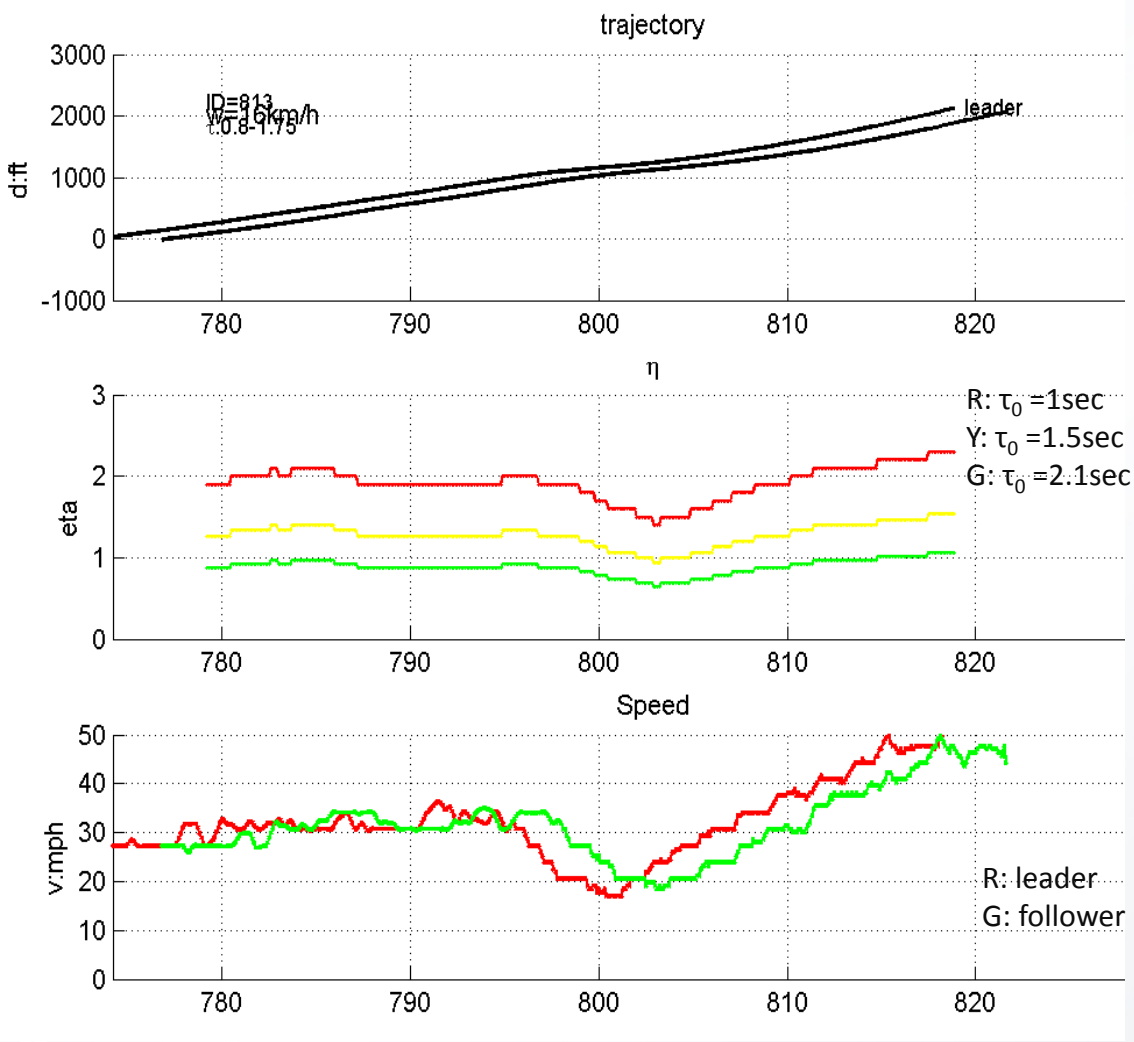
Measurement

Example (1) :



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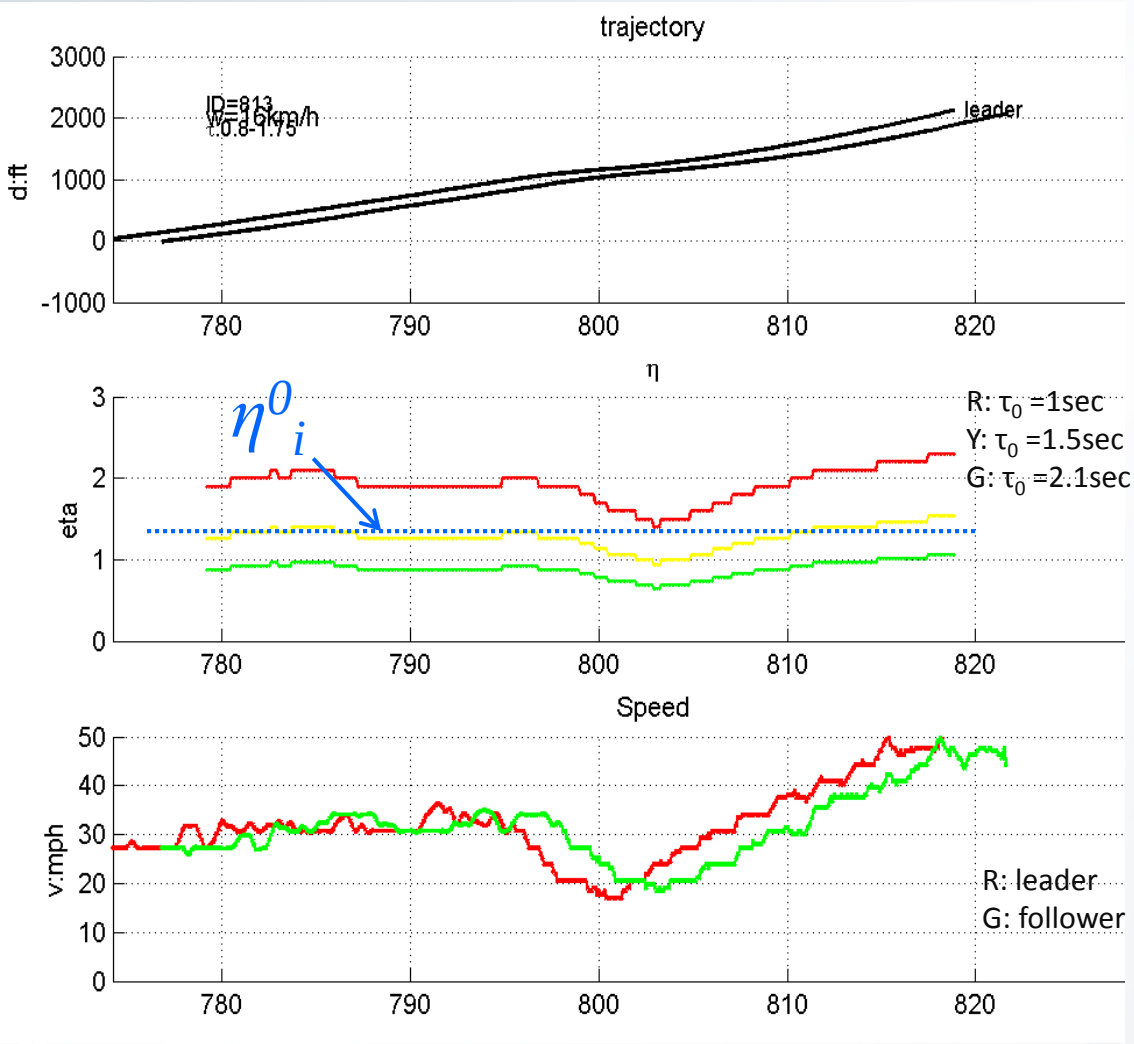
Measurement

Example (1) :



Characteristics of $\eta_i(t)$:

- Remains stable under stationary state- η^0_i.

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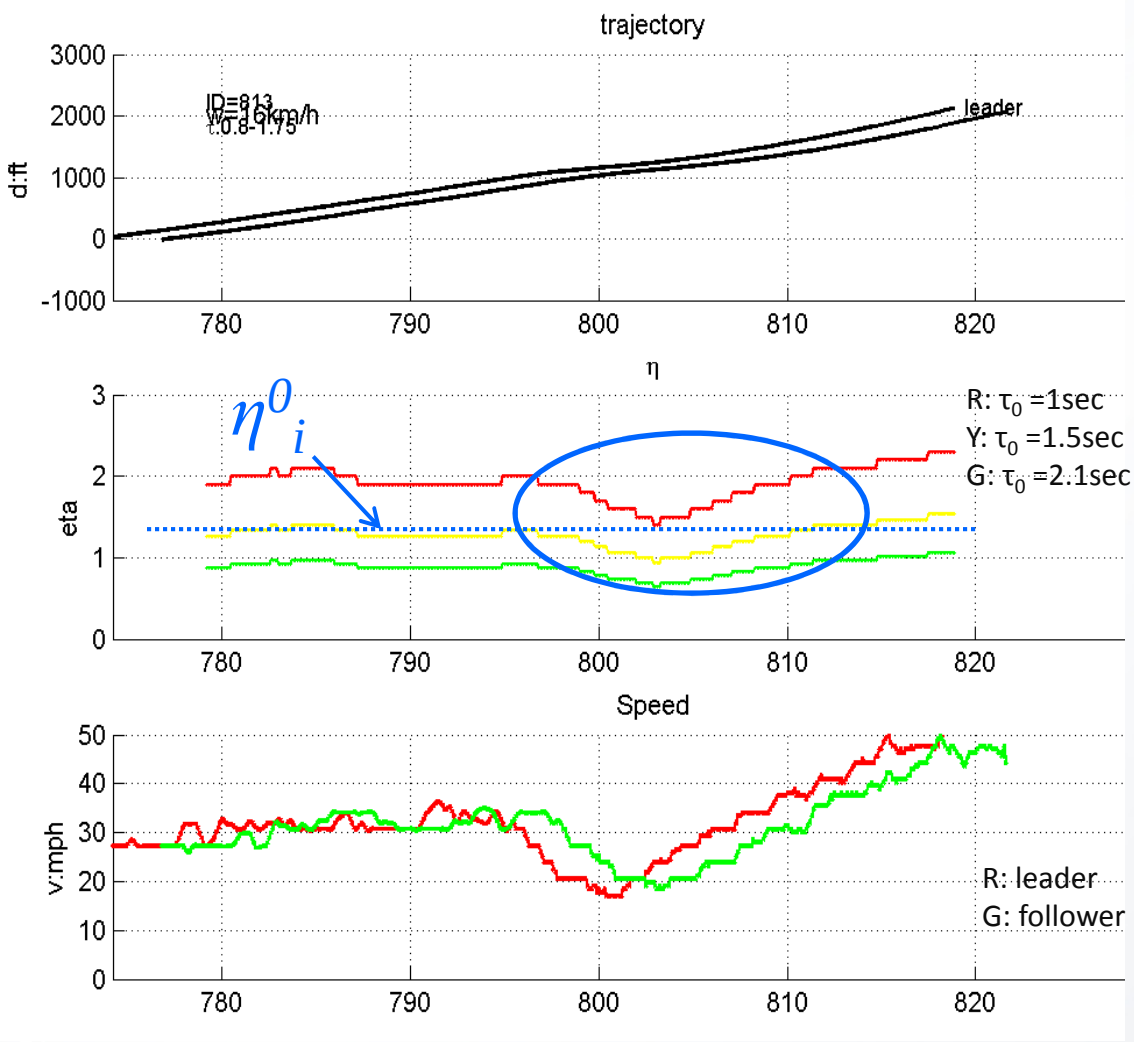
Measurement

Example (1) :



Characteristics of $\eta_i(t)$:

- Remains stable under stationary state- η^0_i.
- Tends to decrease/increase when oscillation wave starts.
- Tends to be stable again after oscillation passes.

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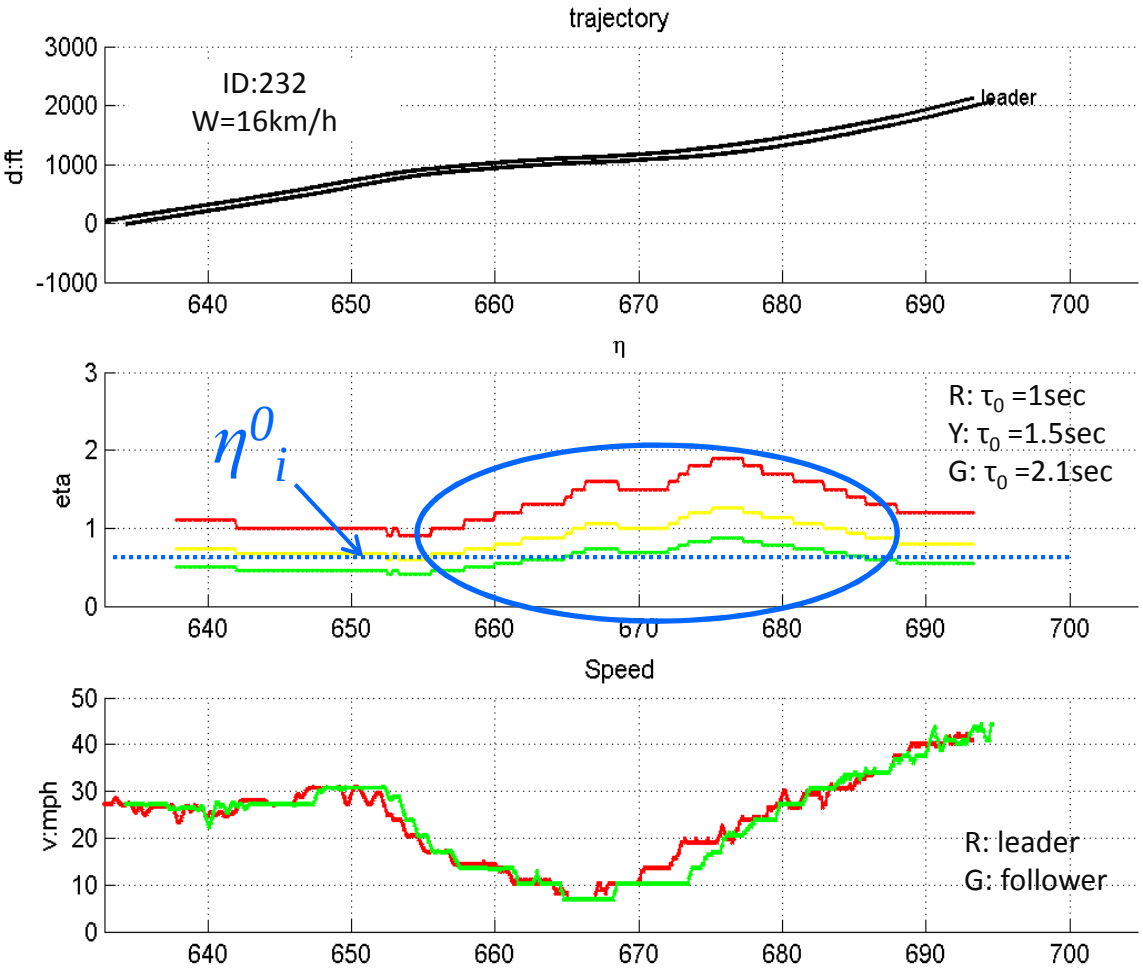
Measurement

Example (2) :



Characteristics of $\eta_i\,(t)$:

- $\eta_i\,(t)$ may go up-down or down-up, or remain constant.
- η^0_i varies from 0.4~2.5

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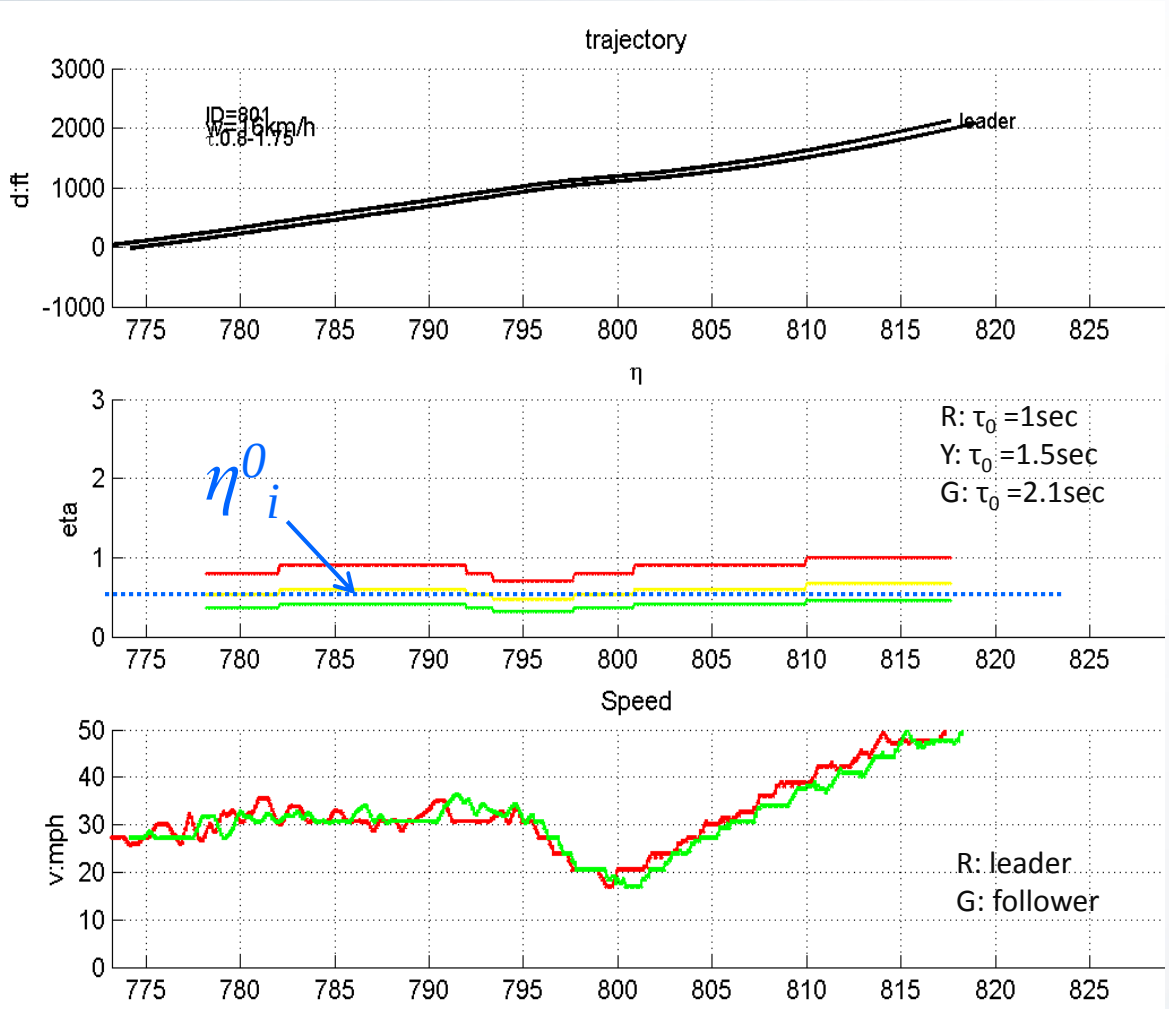
Measurement

Example (3) :



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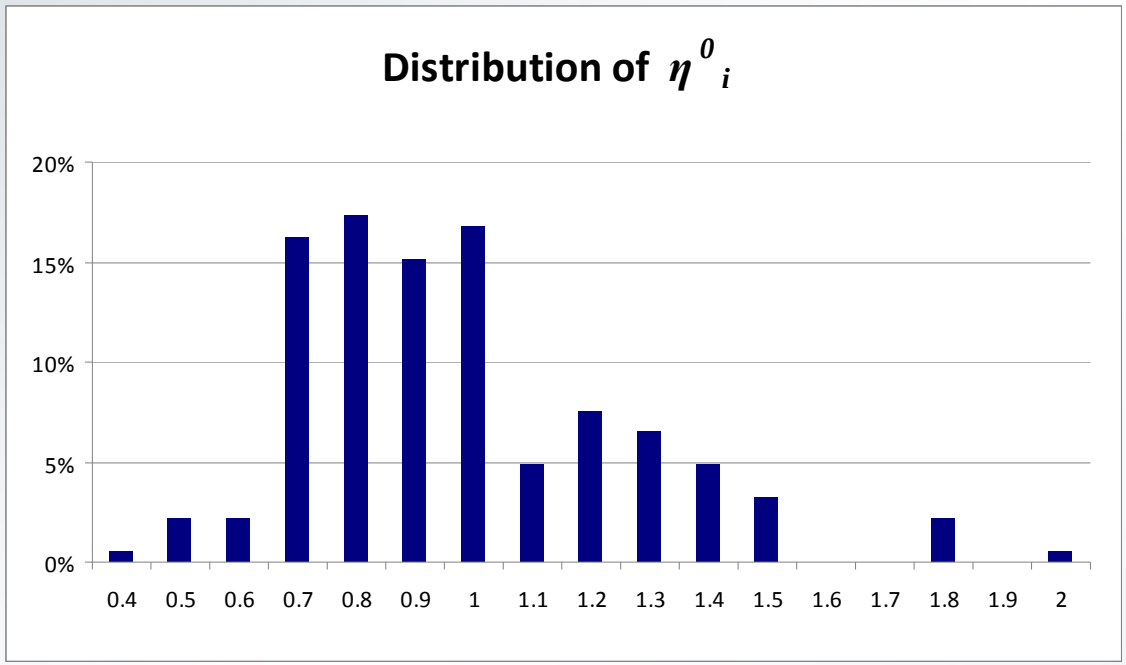
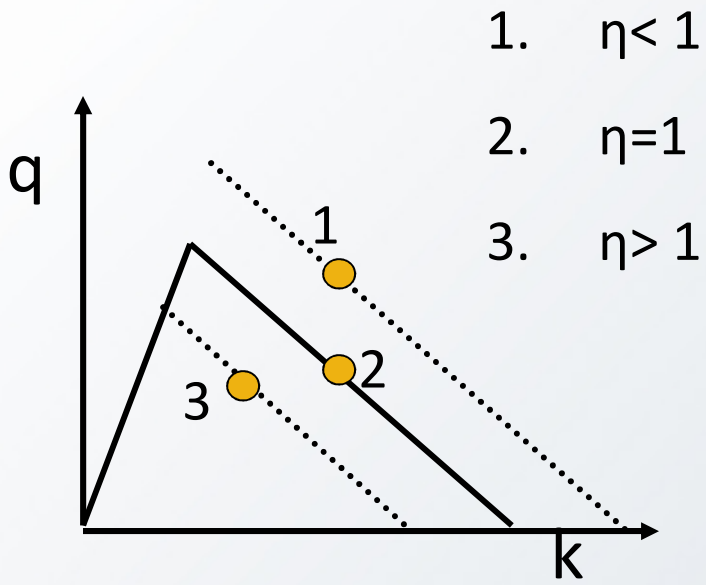
Measurement

Statistics Results

If set: τ_0 ~1.5sec

- η^0_i mean: 0.97, variance:0.28





1. η< 1
2. η=1
3. η> 1

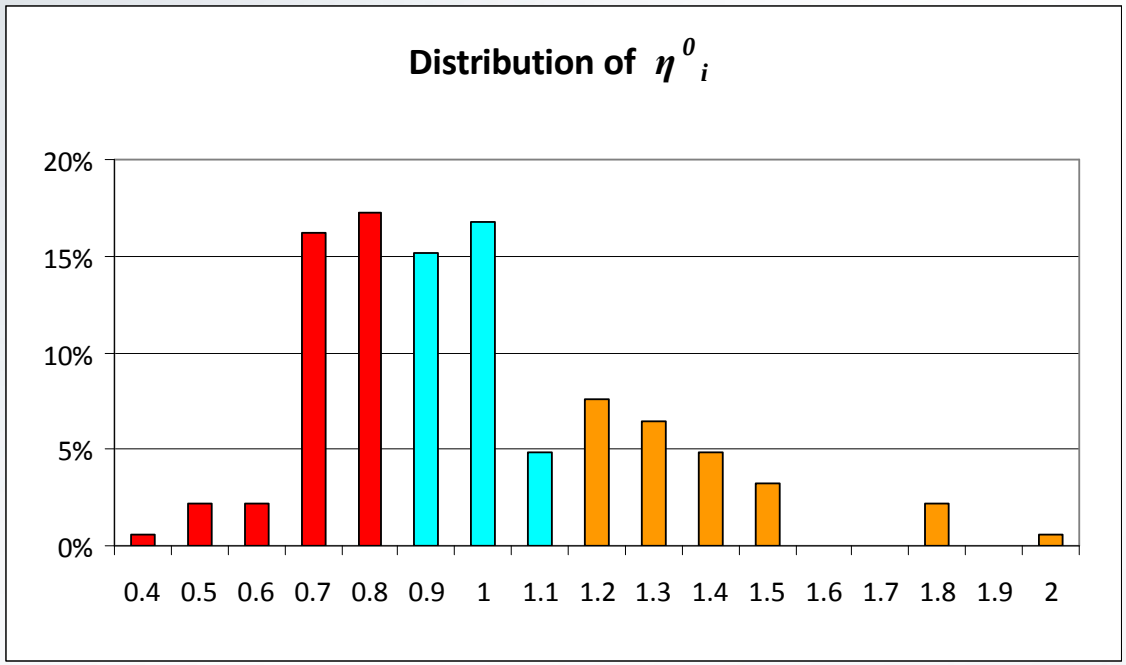
Sample size: 185

Measurement

Statistics Results

If set: τ_0 ~1.5sec

- η^0_i : mean: 0.97, variance:0.28



Sample size: 185

Driver categories:

- Originally aggressive driver:
  $\eta^0_i < 0.9$
- Originally timid driver:
  $\eta^0_i > 1.1$
- Newell driver:
  $0.9 \leq \eta^0_i \leq 1.1$

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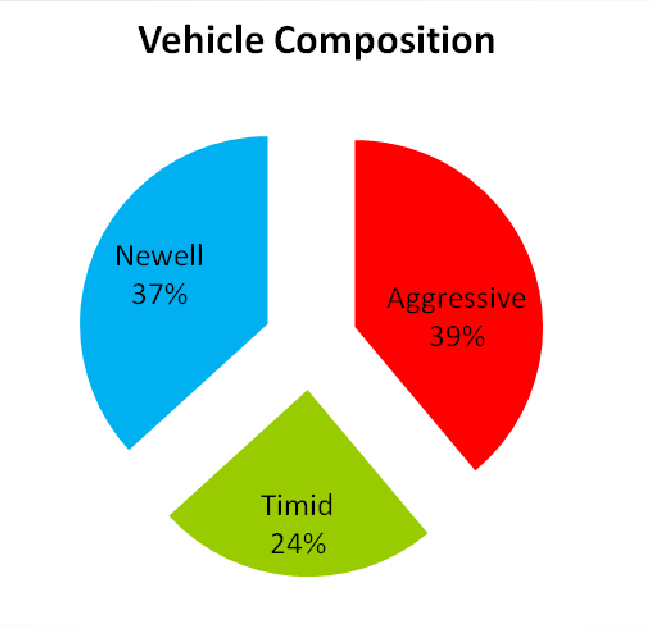
Measurement

Statistics Results

If set: τ_0 ~1.5sec

- η^0_i : mean: 0.97, variance:0.28



Sample size: 185

Driver categories:

- Originally aggressive driver:

$$\eta^0_i < 0.9$$

- Originally timid driver:

$$\eta^0_i > 1.1$$

- Newell driver:

$$0.9 \leq \eta^0_i \leq 1.1$$

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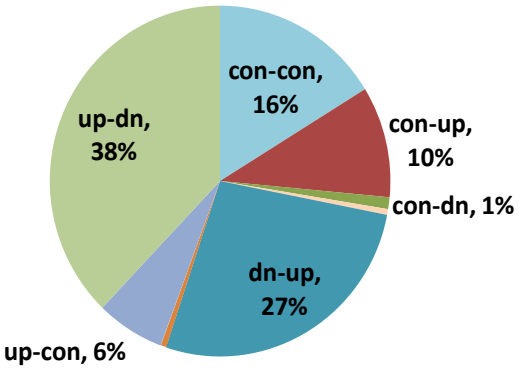
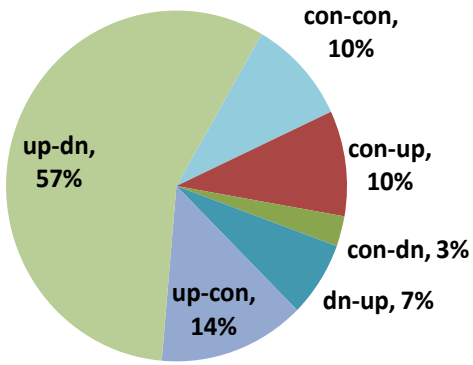
Measurement

Behavior Patterns (change of $\eta_i(t)$)

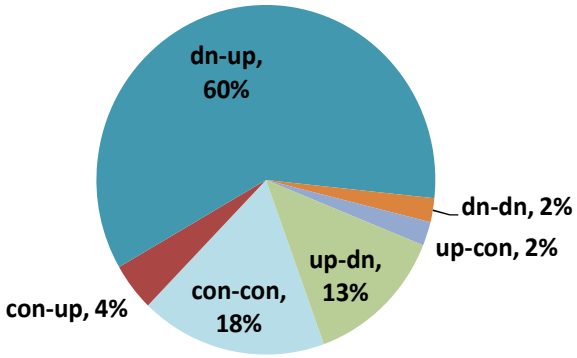
All Drivers



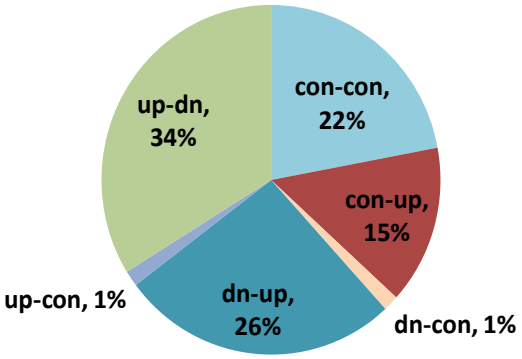
Originally AG



Originally TM



Originally NW



Dominant patterns:

- AG: up-down
- TM: down-up
- NW: up-dn, dn-up, con-con.
- All: up-dn, dn-up, and con-con.

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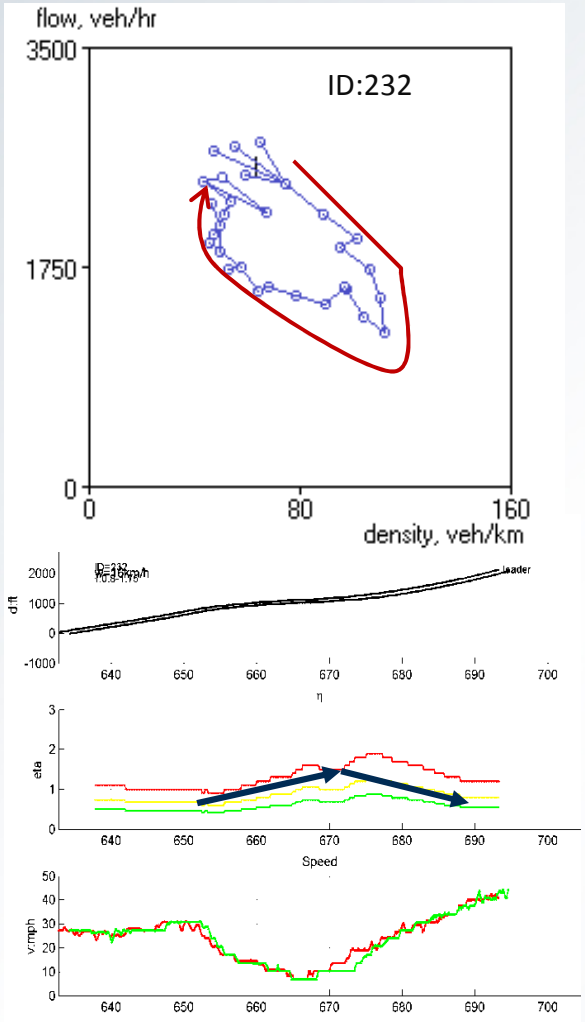
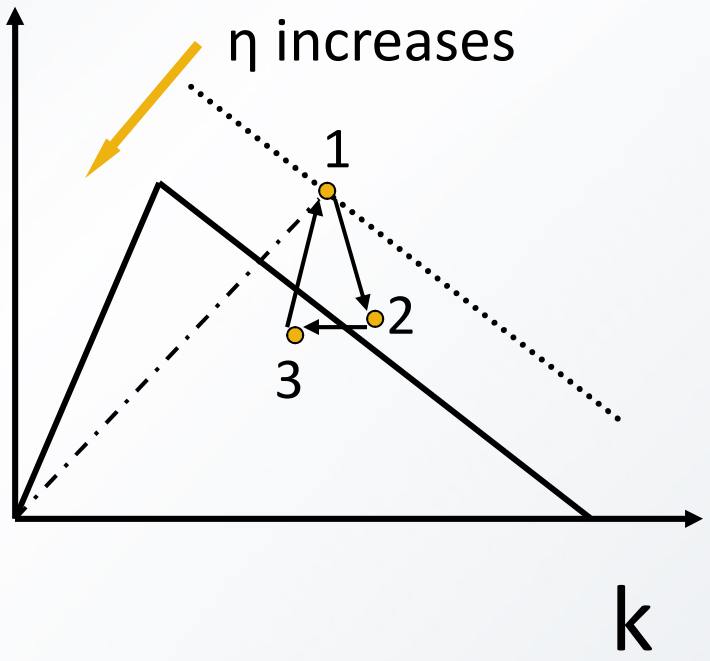
Measurement

Flow-density path (1) Clock-wise oriented: up-down pattern

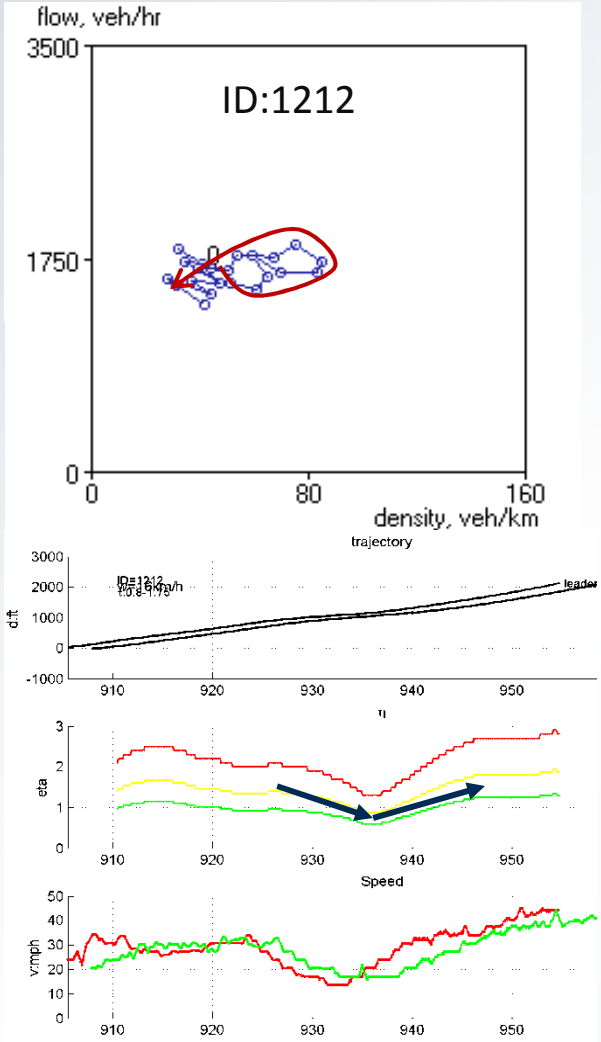


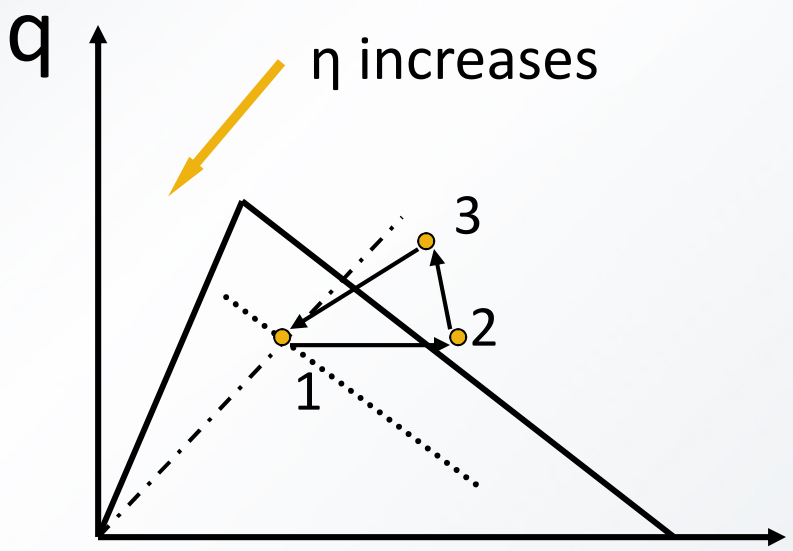


Measurement

Flow-density path (2)

Counter clock-wise oriented: down-up pattern





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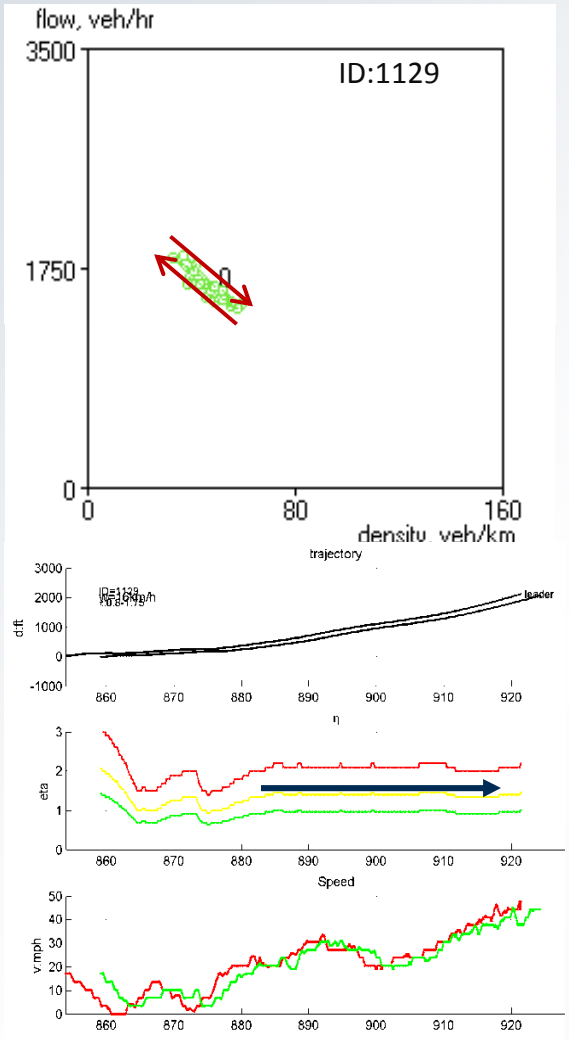
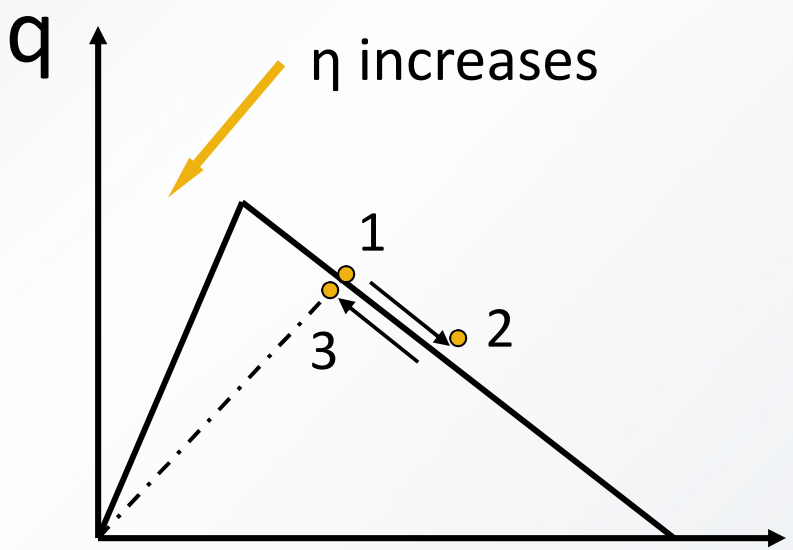
Measurement

Flow-density path (3) Straight line oriented: con-con pattern





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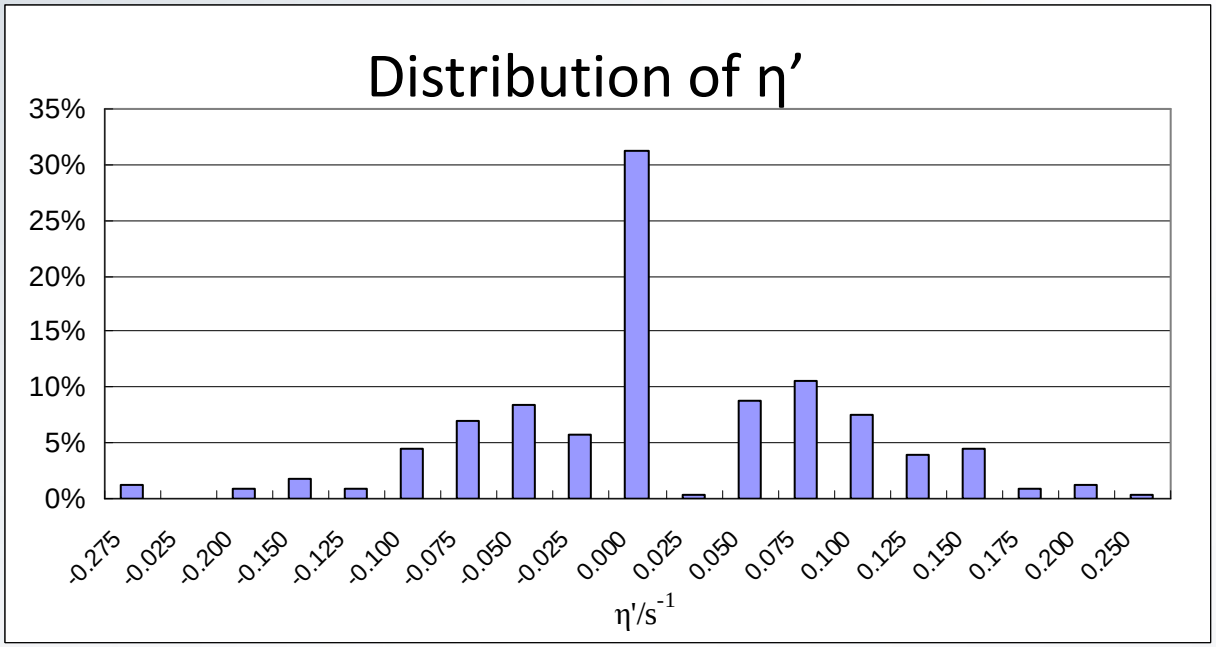
Measurement

Distribution of the derivative of η

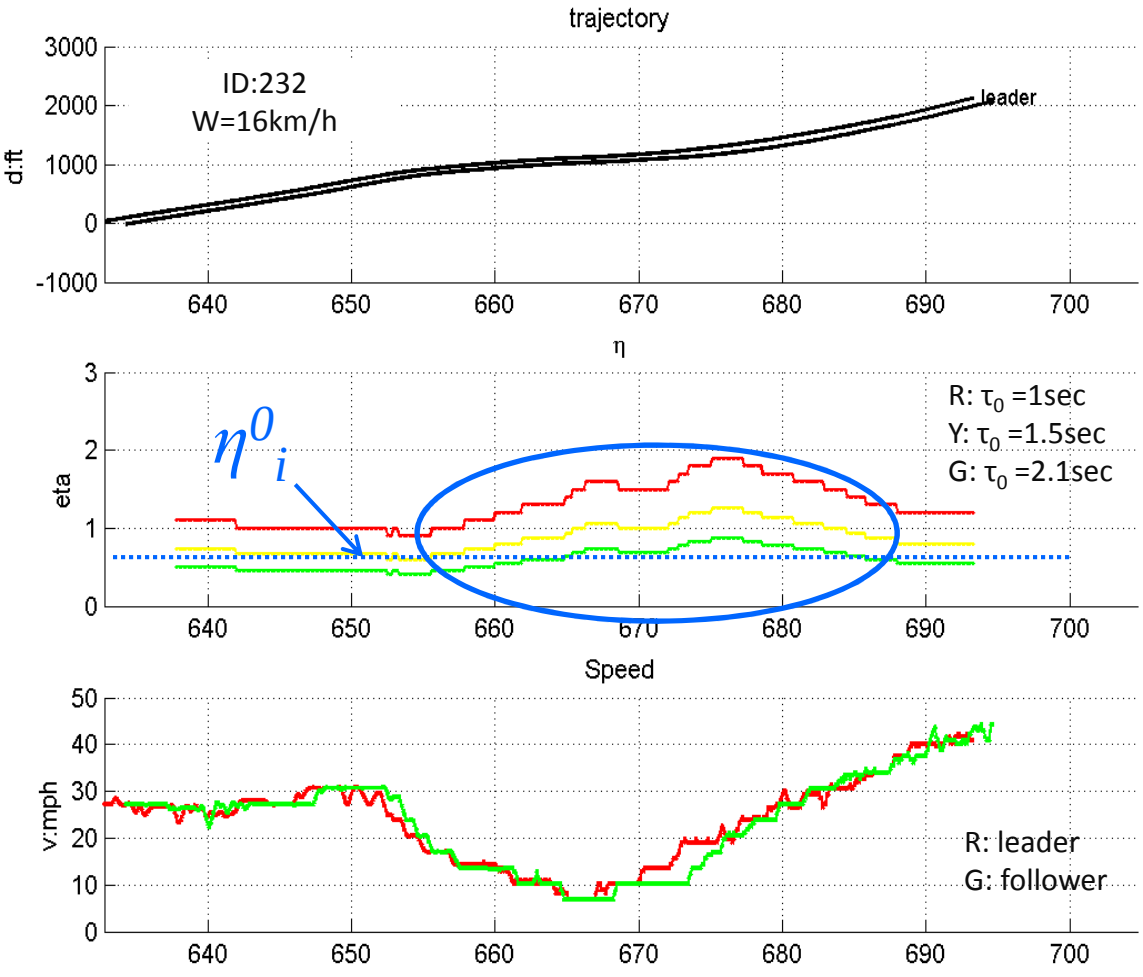


Sample size: 227

- Normal?

Measurement

Example (2) :



Characteristics of $\eta_i\,(t)$:

- $\eta_i\,(t)$ may go up-down or down-up, or remain constant.
- η^0_i varies from 0.4~2.5

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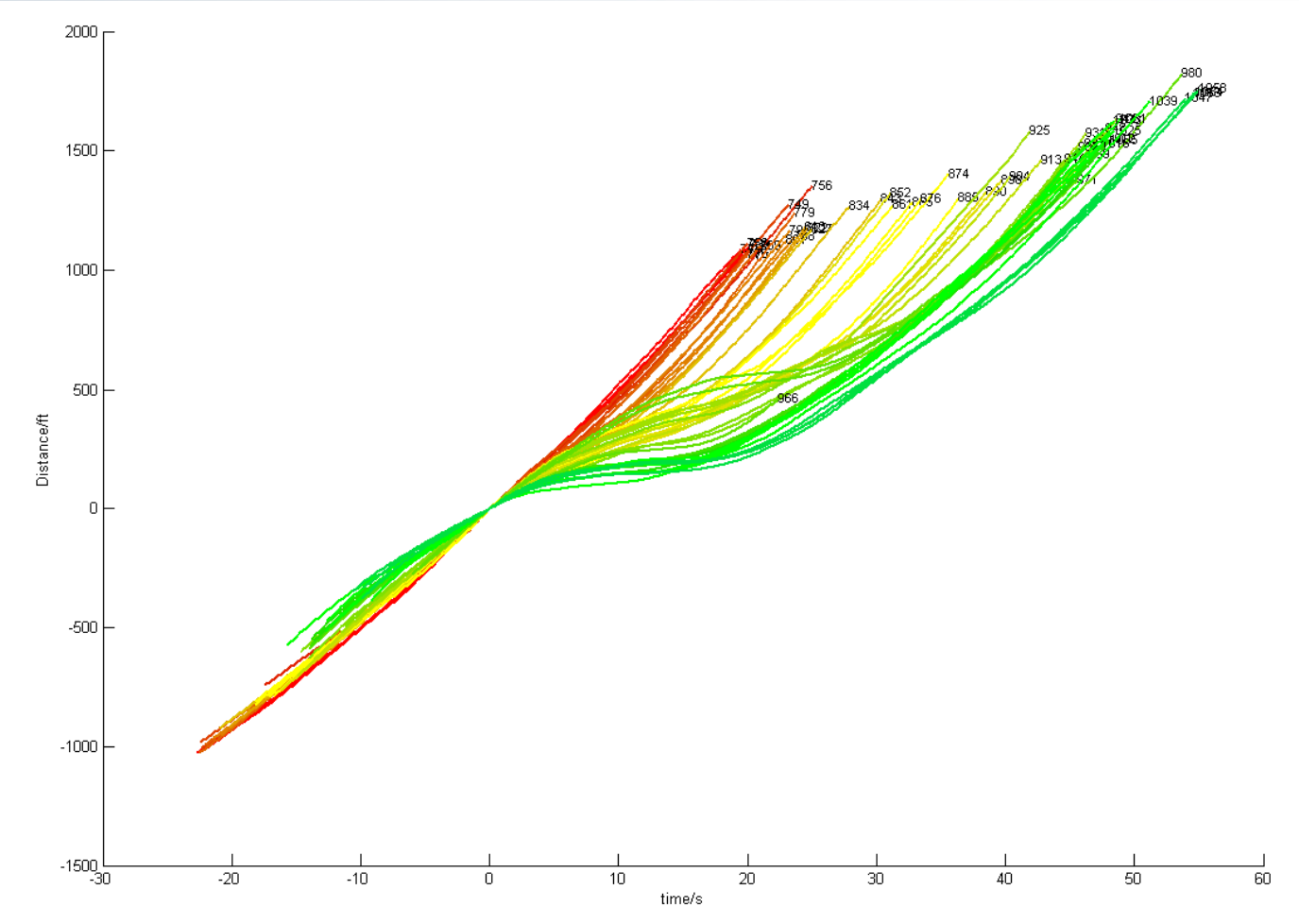
Application

Example: an oscillation sequence



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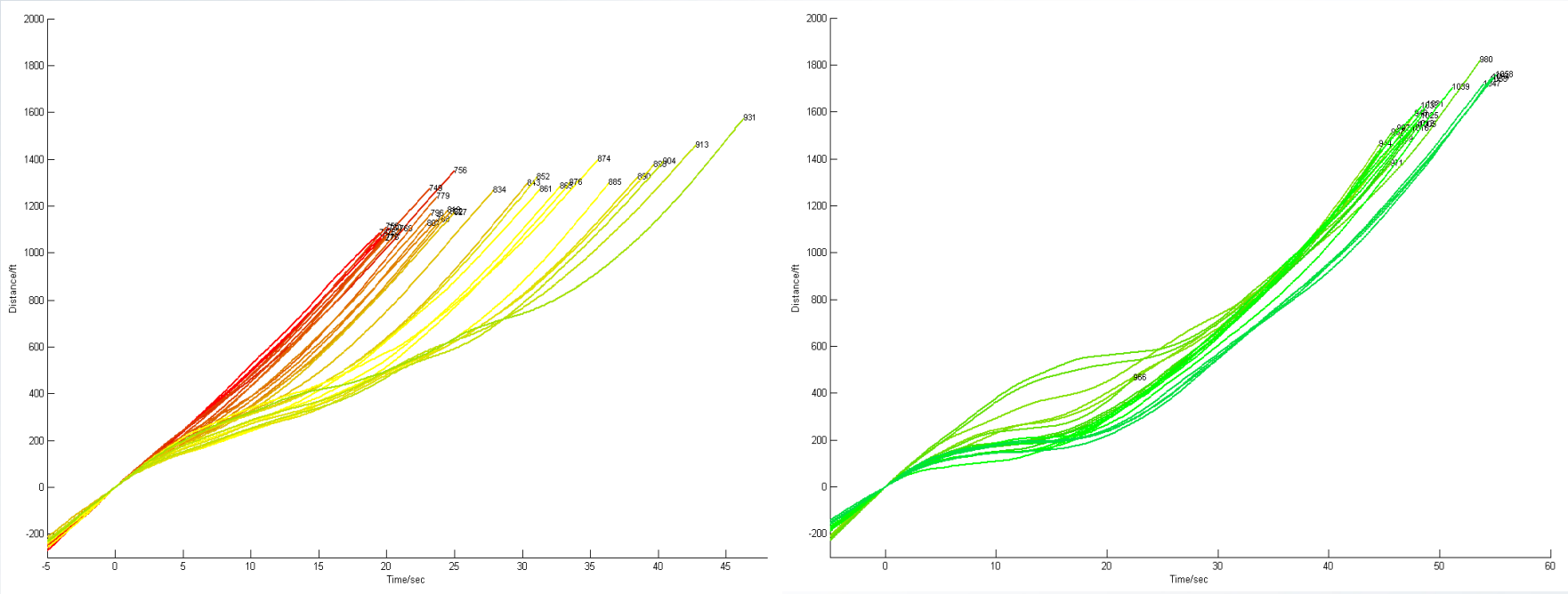
Application

Different steps in an oscillation sequence



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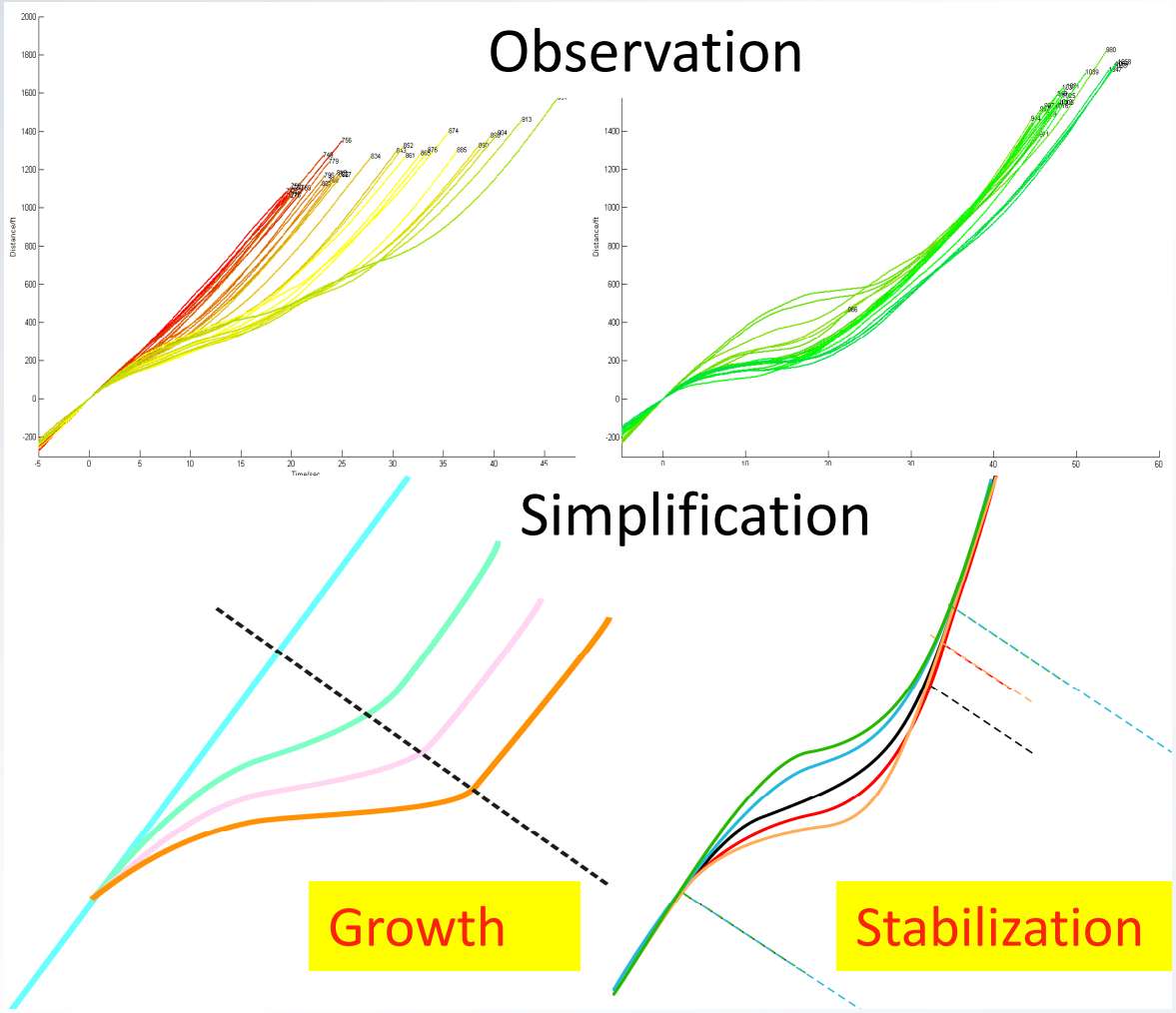
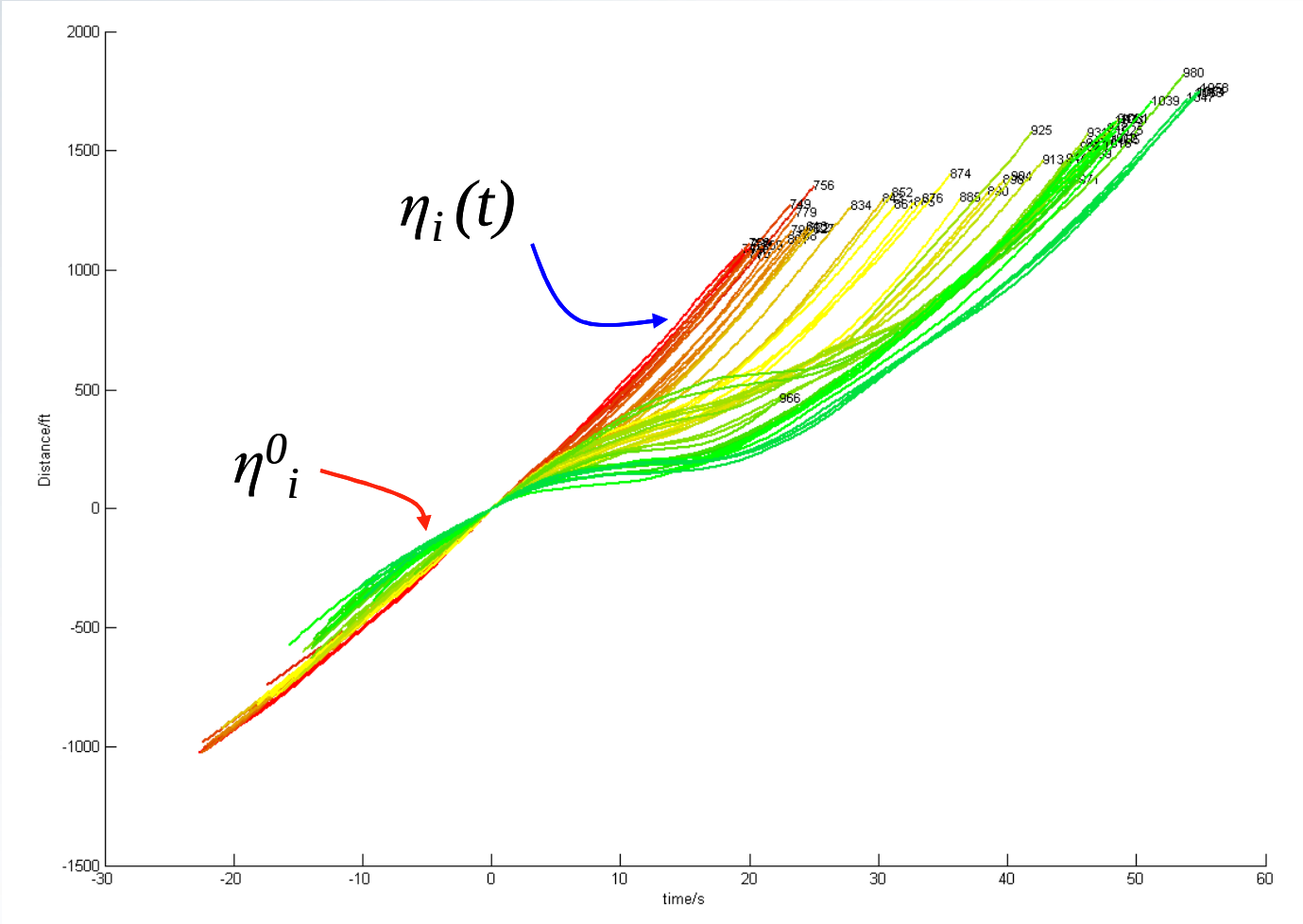
Application

Different steps in an oscillation sequence



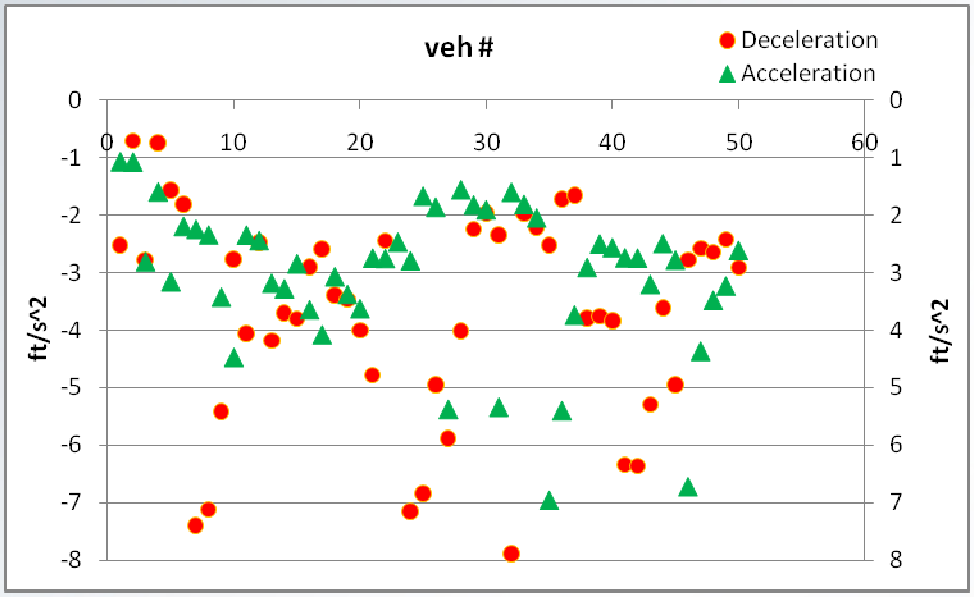
Application

Simulation



Appendix

Deceleration and acceleration of vehicles



- Each trajectory has a deceleration and acceleration cycle. So the deceleration and acceleration rates of a vehicle are shown by an orange and green dot respectively.
- All these trajectories are in one oscillation sequence.

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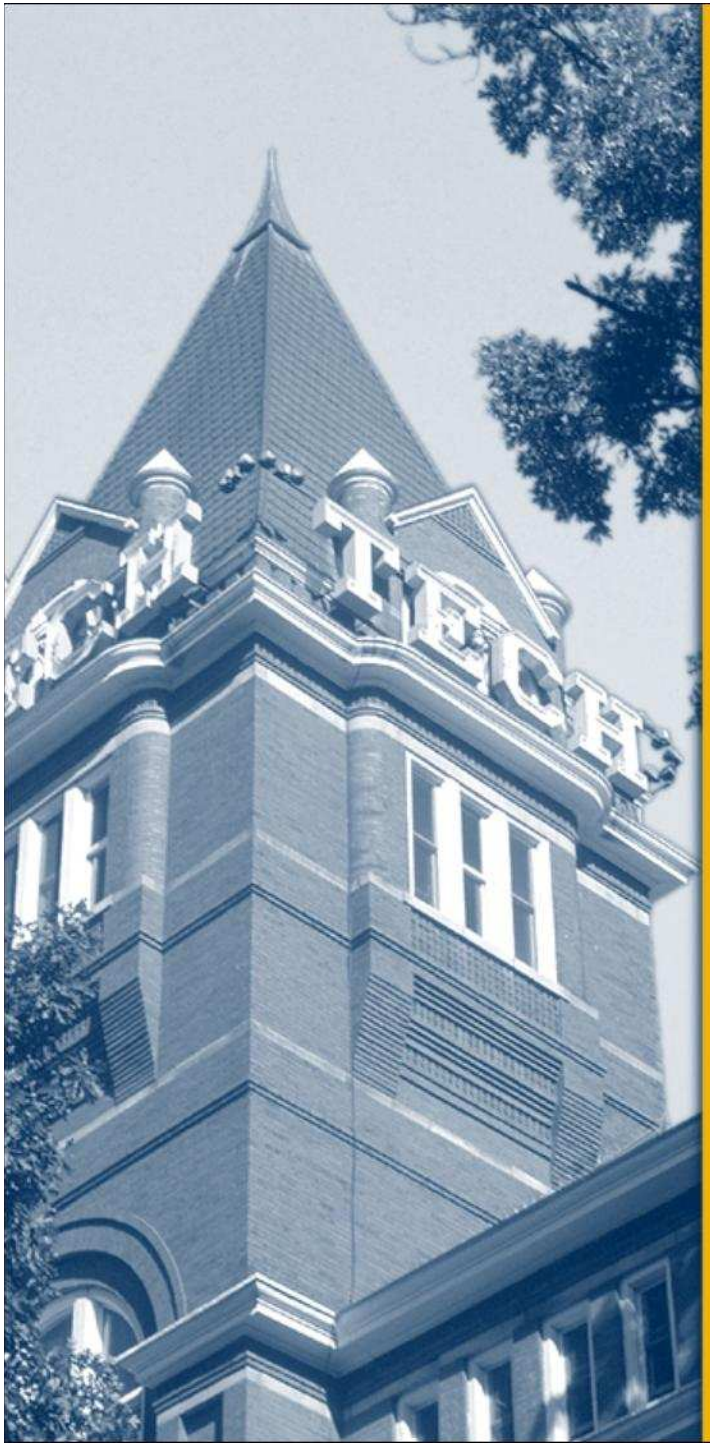

Thank you!

Any question?

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