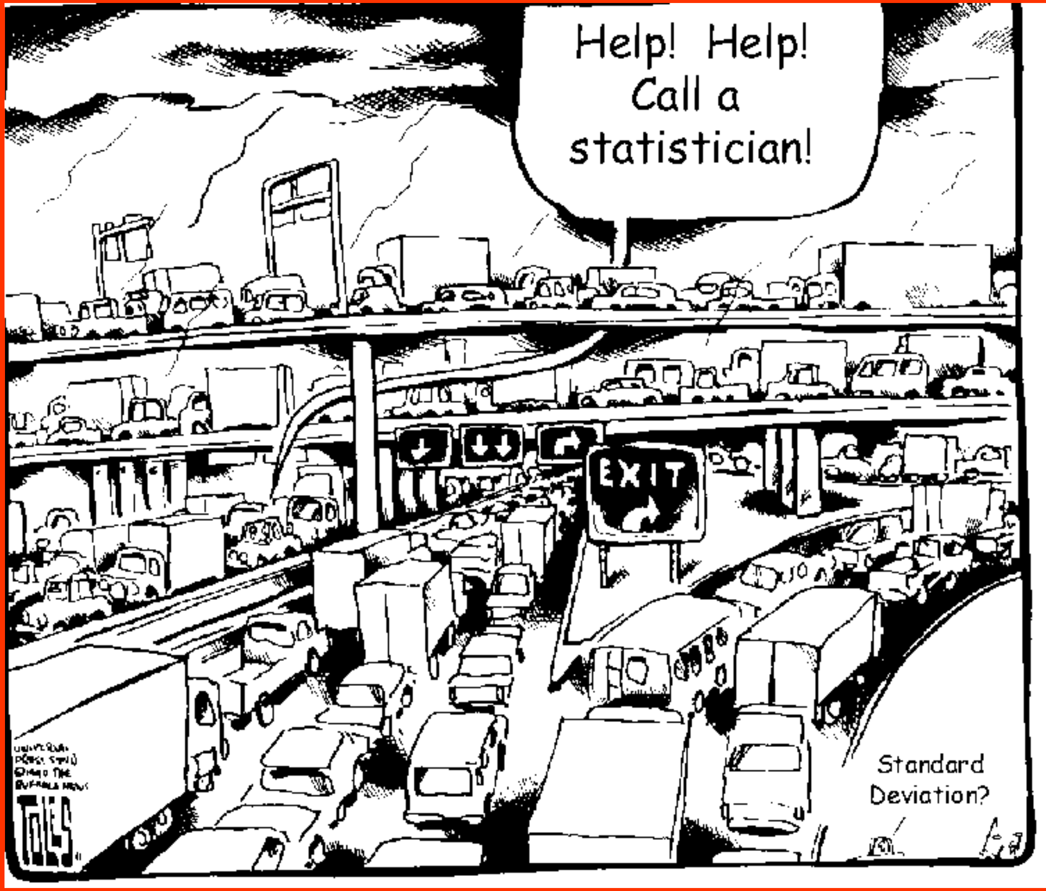
Measuring Traffic



John Rice

University of California, Berkeley

People

EECS

Stuart Russell
Jitendra Malik
Alistair Sinclair
Pravin Varaiya
Chao Chen
Zhanfeng Jia
Dan Lyddy

Statistics

Peter Bickel
John Rice
Xiaoyan Zhang
Jaimyoung Kwon
Erik van Zwet

Transportation

Ben Coiffman
Alex Skabardonis

Outline of Talk

The Freeway Performance Measurement System

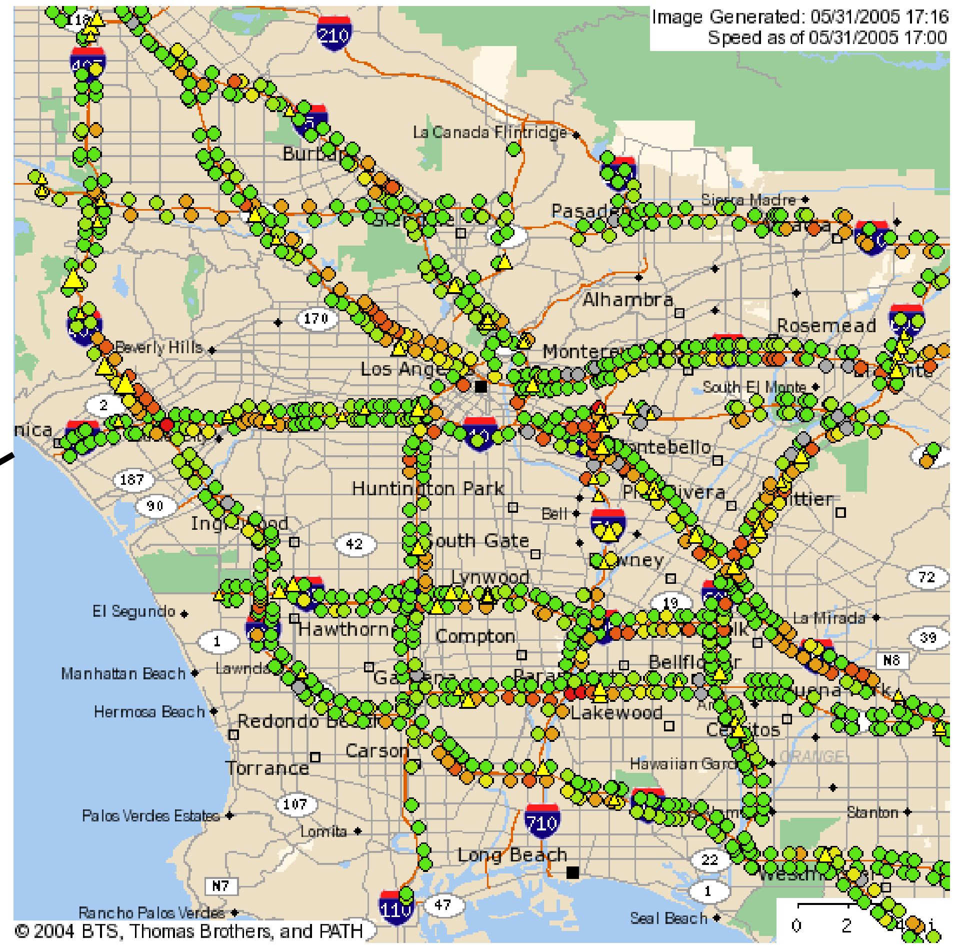
- Information from loop detectors
- Predicting travel times on a freeway network

Video Monitoring

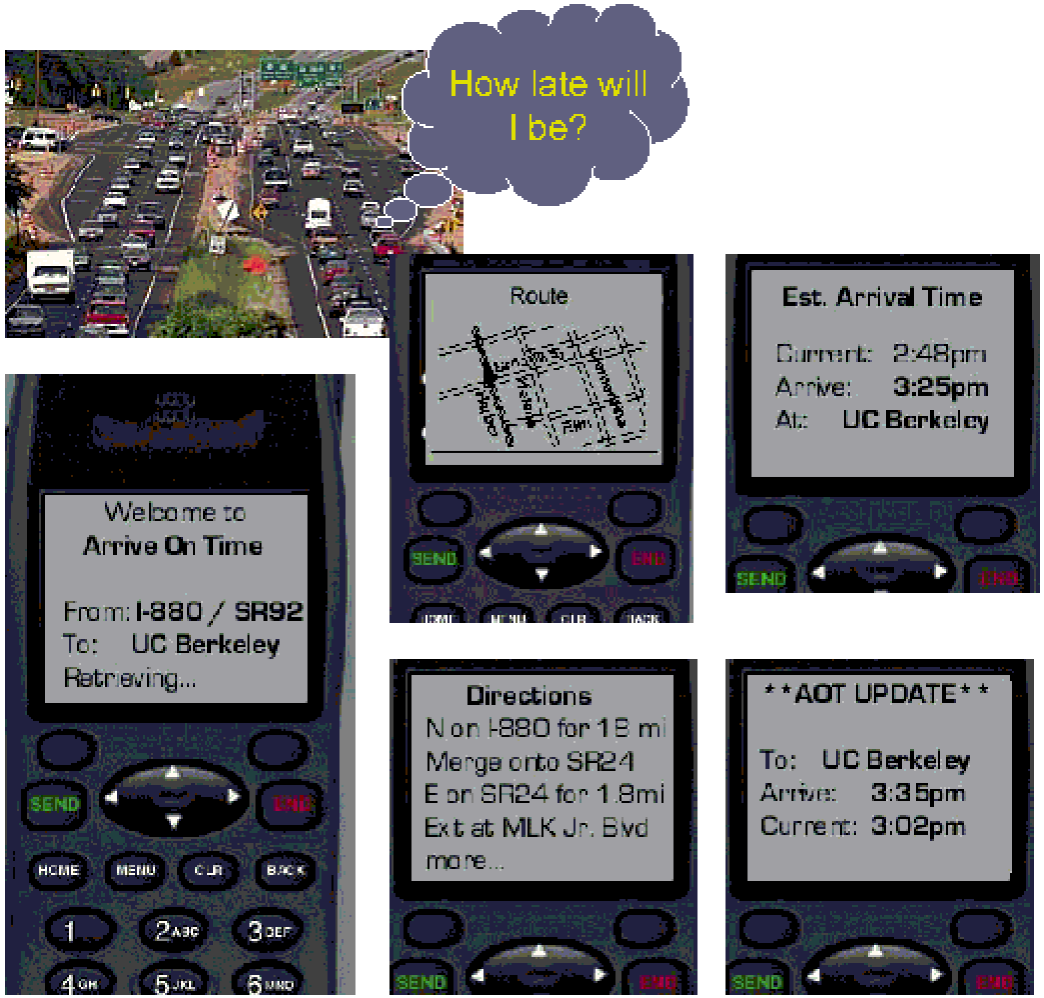
Freeway Performance Measurement Project

PATH — Partners for Advanced Transit and Highways

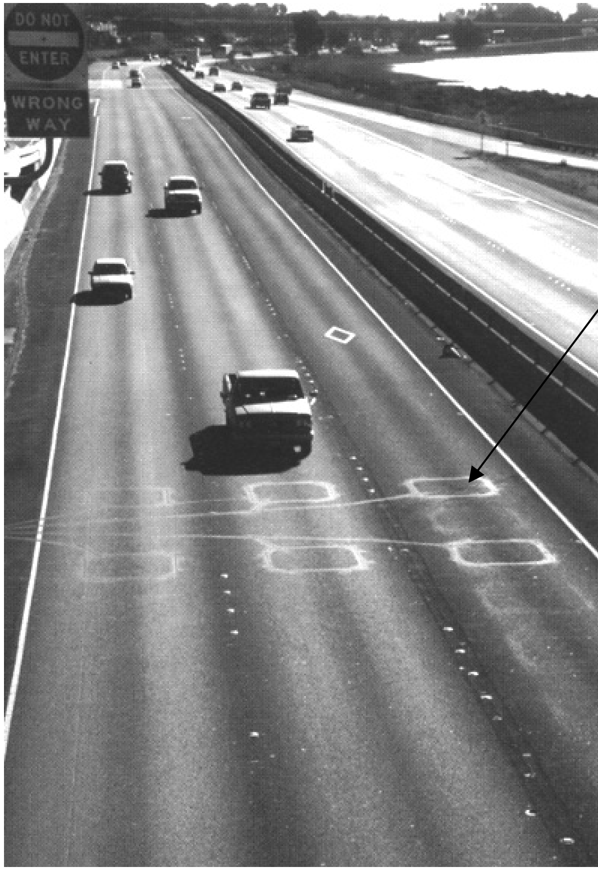
Caltrans



Web Site


How late will I be?
Route
Est. Arrival Time
Current: 2:48pm
Arrive: 3:25pm
At: UC Berkeley
Welcome to
Arrive On Time
From: I-880 / SR92
To: UC Berkeley
Retrieving...
Directions
N on I-880 for 18 mi
Merge onto SR24
E on SR24 for 1.8mi
Exit at MLK Jr. Blvd
more...
AOT UPDATE
To: UC Berkeley
Arrive: 3:35pm
Current: 3:02pm
SEND
END
HOME
MENU
CLR
BACK

Data Source: Loop Detectors



Loops are typically located about every ½ mile on freeways

Flow = number of vehicles per 5 minutes. Flow is sometimes also called *volume*.

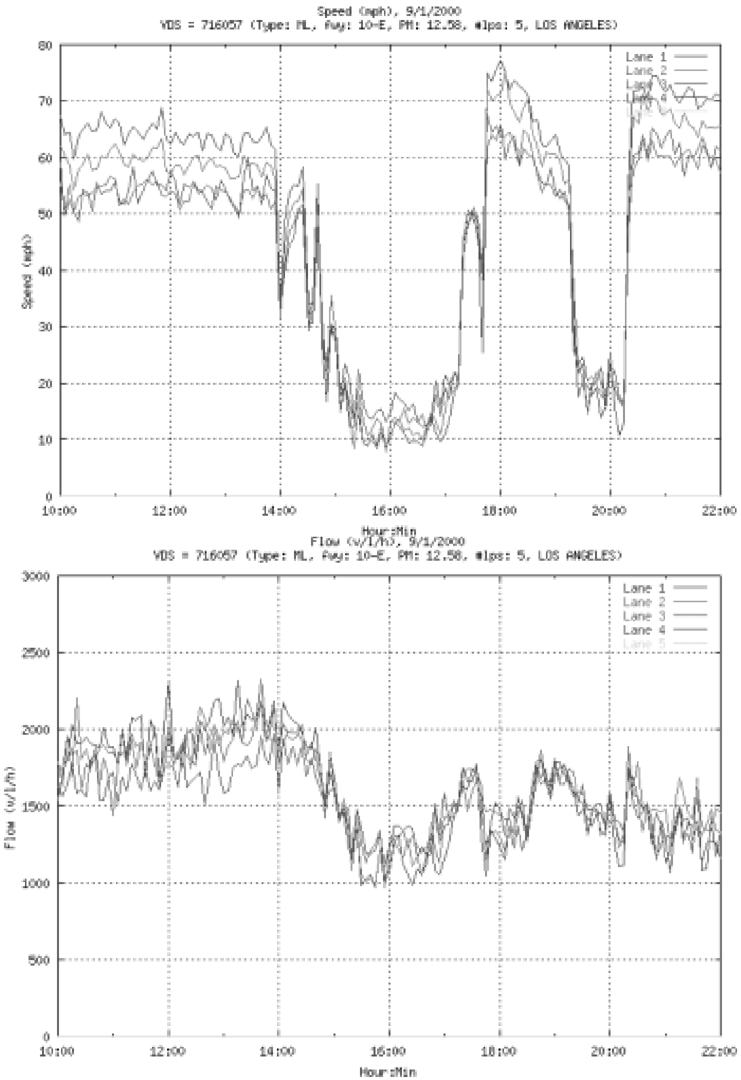
Occupancy = percentage of time a vehicle is over the loop

The loops in the figure are “double loops,” from which velocity can be measured, too. Single loops are more common and from them only flow and occupancy can be measured.

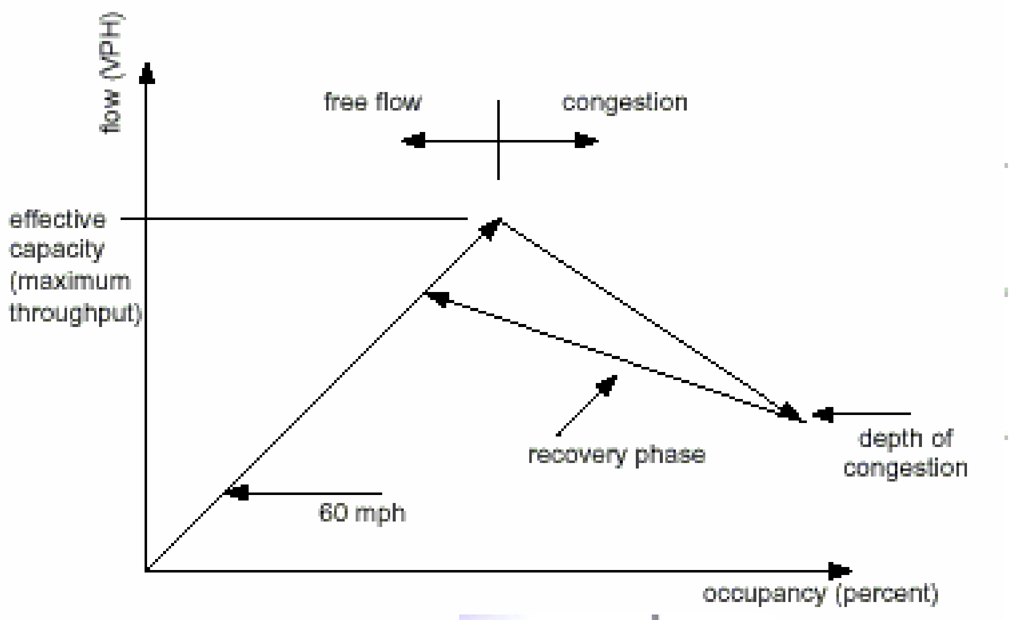
The PeMS system receives flow and occupancy from approximately 22,000 loops across the state every 30 seconds: 2 GB per day. Currently store 4 TB of data

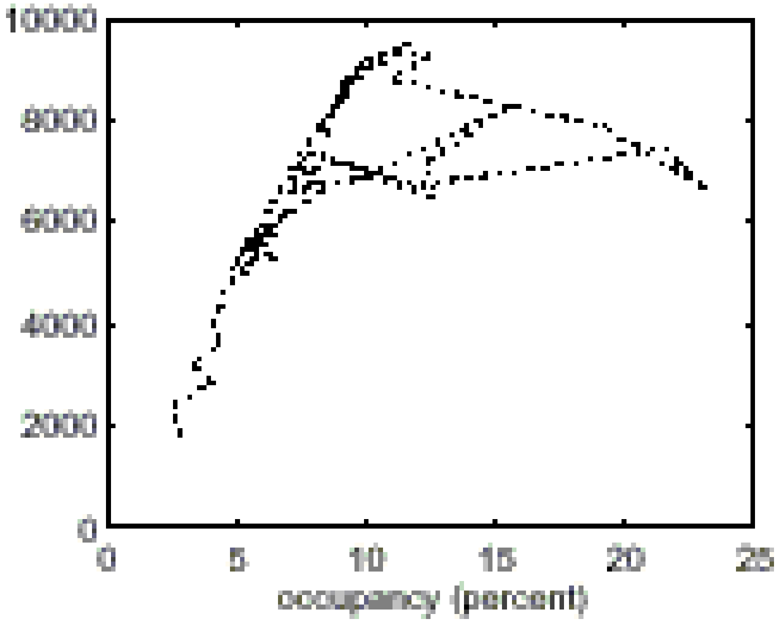
Local Information from Loop Detectors

Figure 1. Data from 5 lanes of I-10E at PM 12.58 on 9/1/2000: congestion starts at 2:00 pm, speed drops to 10 mph and flow to 1200 vehicles per lane per hour. (Source: PeMS)



Dynamics: Flow versus Occupancy

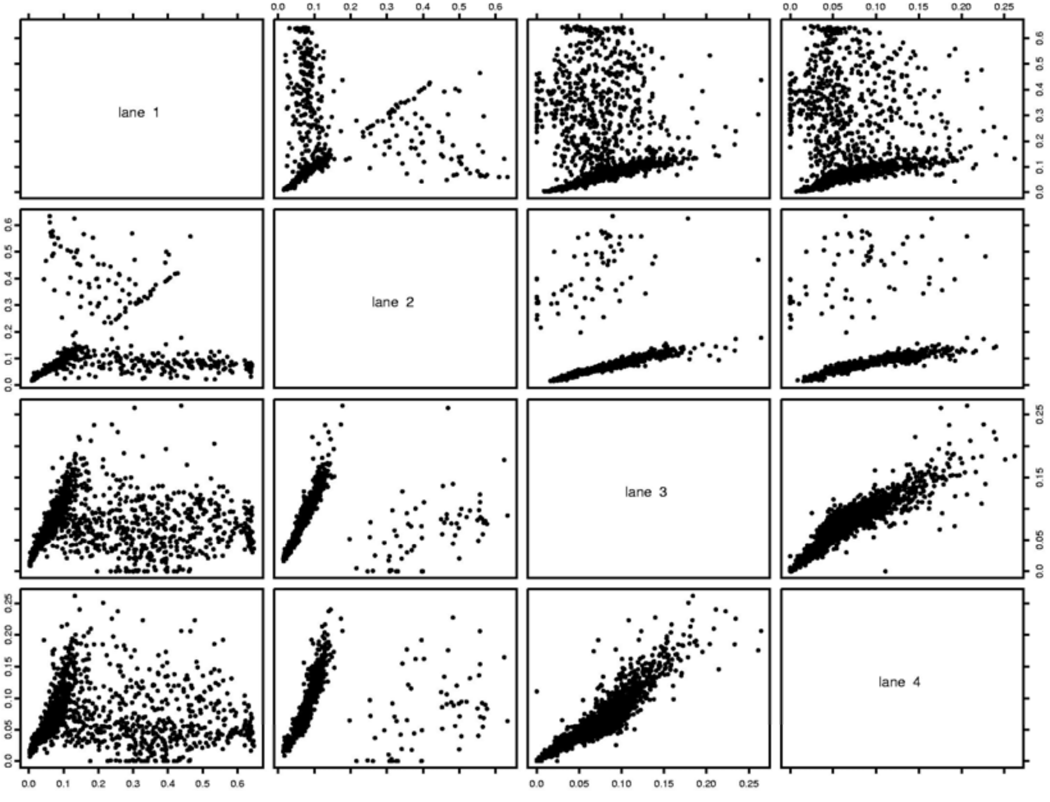




On-ramp meters try to keep occupancy below critical point

Data Volume and Quality

Often data are missing or invalid. PeMS imputes such values



Travel Time Prediction

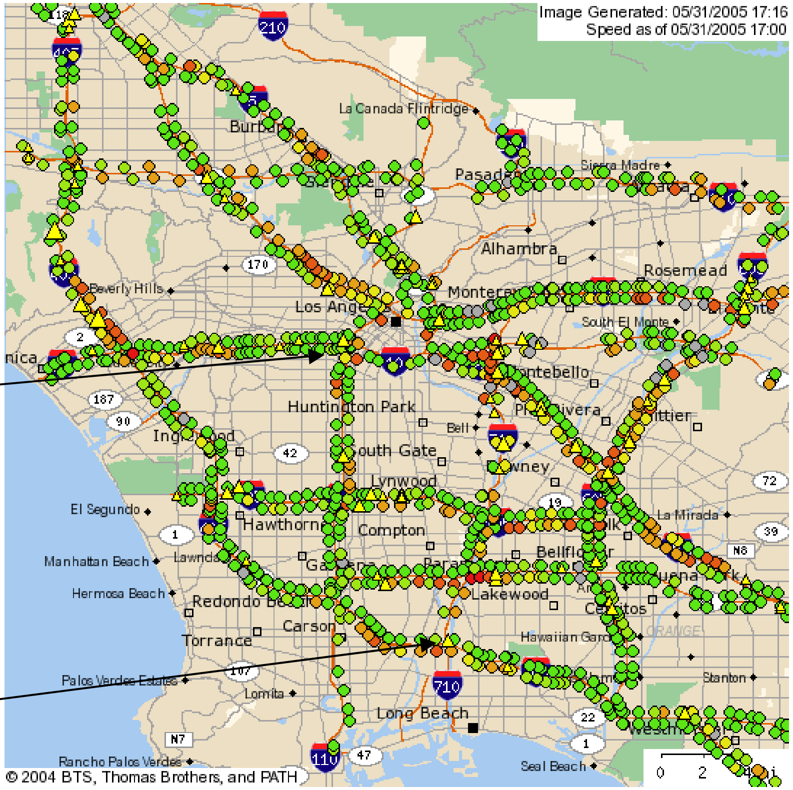
Suppose a traveler wishes to go from some origin to some destination at a particular time. For example, it is now 10 am and he wishes to leave the origin at 10:30 am.

Problem: estimate travel time and find route with shortest travel time.

[PeMS route guidance]

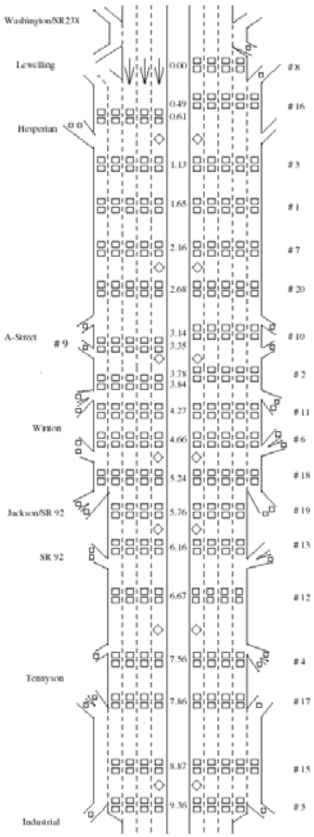
origin

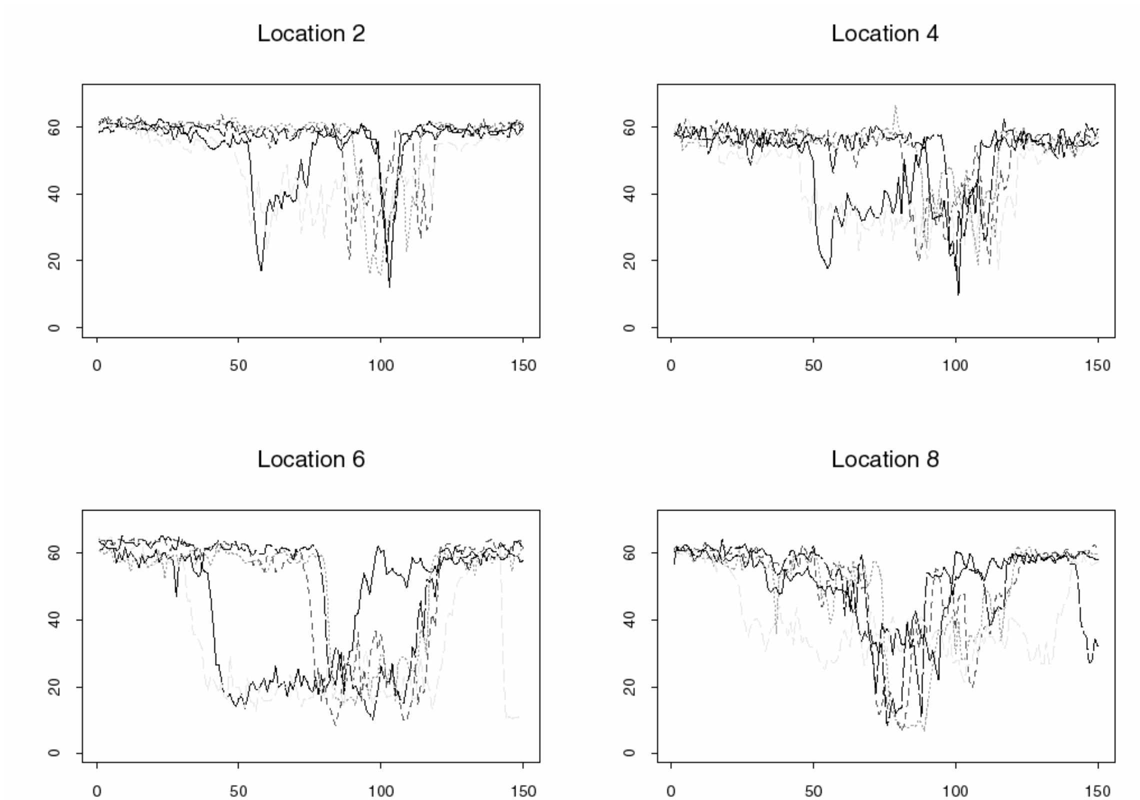
destination

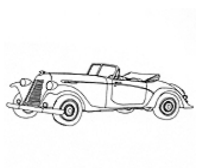


Travel Time Prediction
Example 1: I880

6 mi

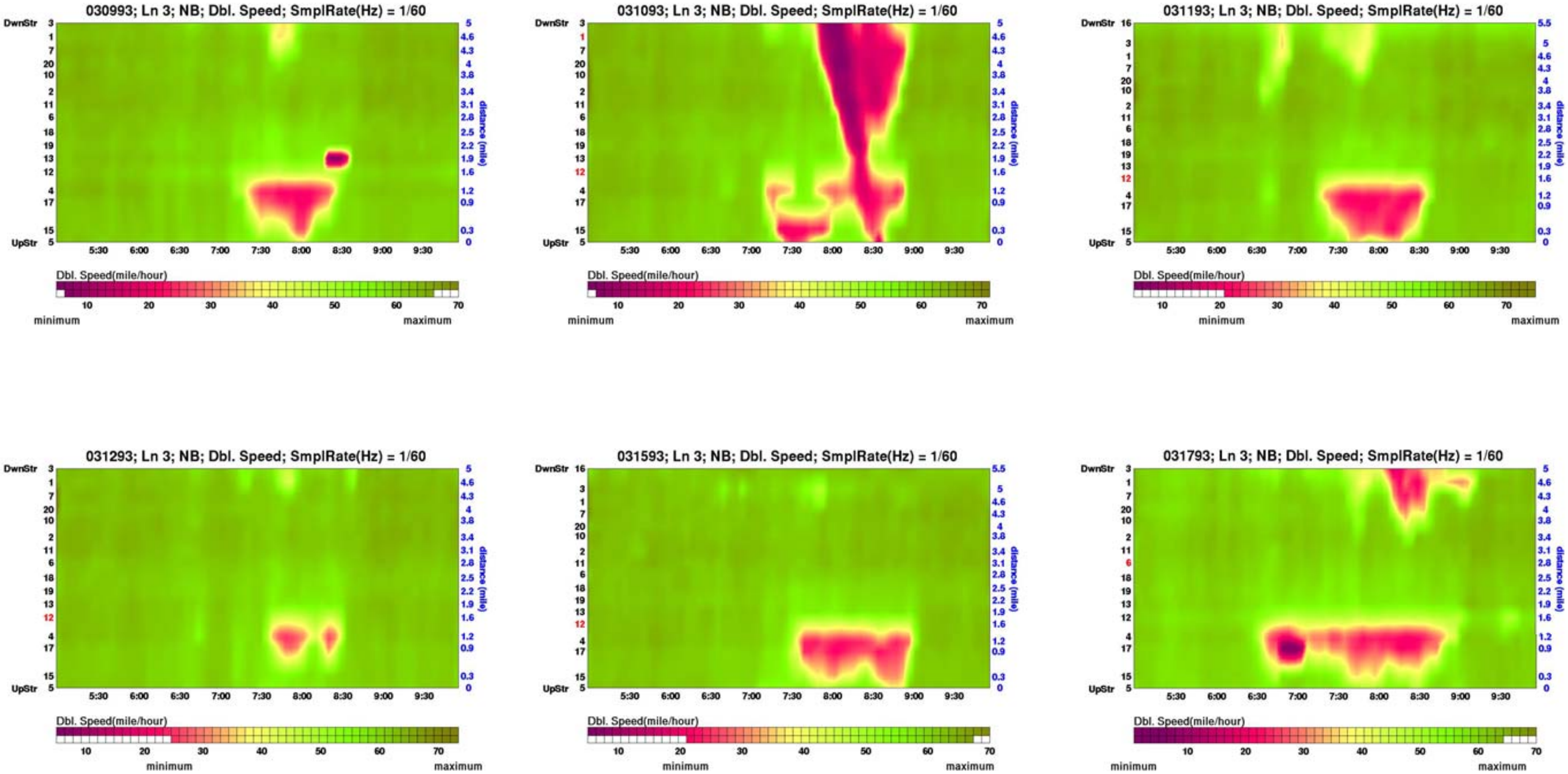






Probe vehicles ⟵ predict ⟵ Velocity

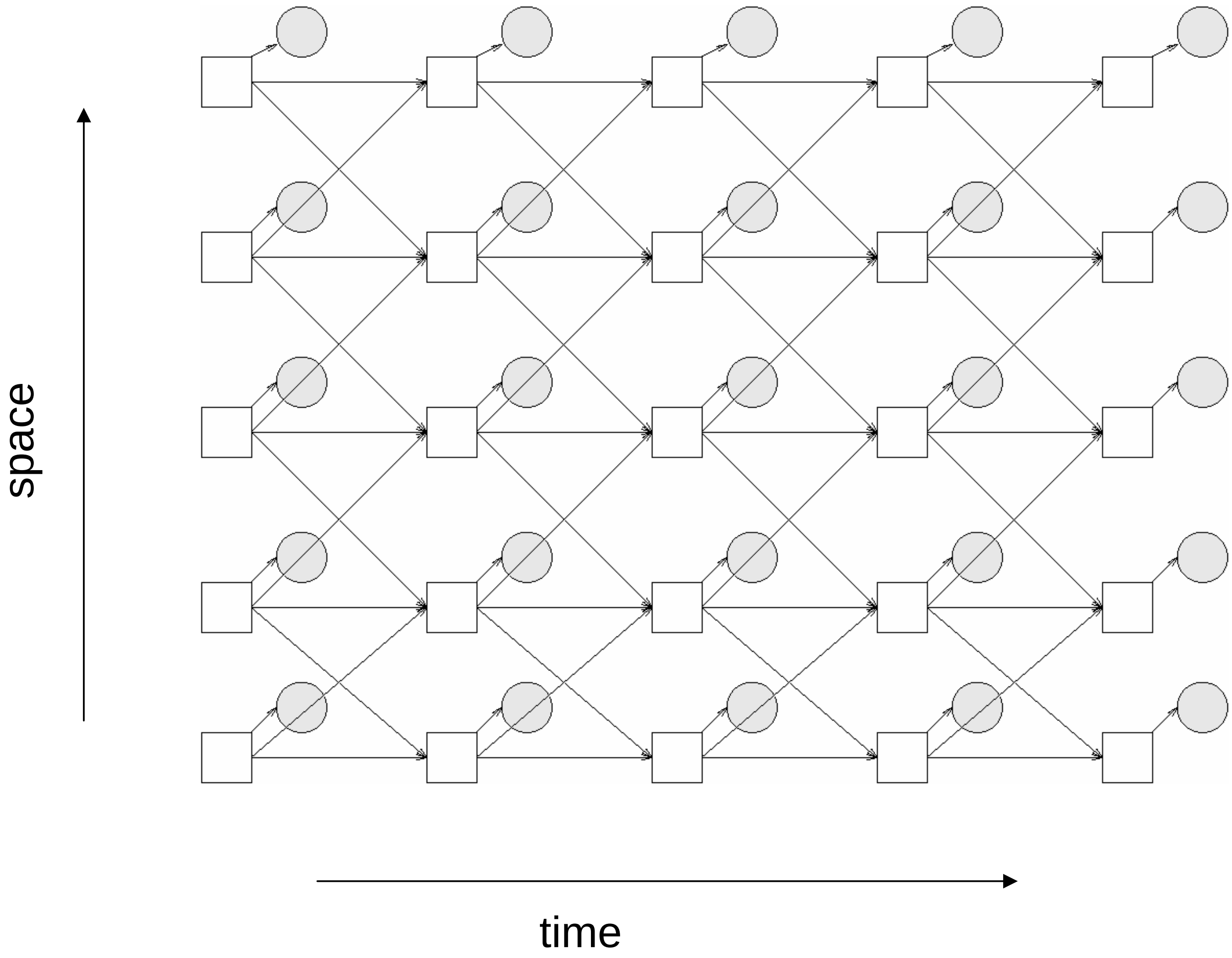
Six Days


030993; Ln 3; NB; Dbl. Speed; SmplRate(Hz) = 1/60
031093; Ln 3; NB; Dbl. Speed; SmplRate(Hz) = 1/60
031193; Ln 3; NB; Dbl. Speed; SmplRate(Hz) = 1/60
031293; Ln 3; NB; Dbl. Speed; SmplRate(Hz) = 1/60
031593; Ln 3; NB; Dbl. Speed; SmplRate(Hz) = 1/60
031793; Ln 3; NB; Dbl. Speed; SmplRate(Hz) = 1/60
DwnStr
UpStr
5:30 6:00 6:30 7:00 7:30 8:00 8:30 9:00 9:30
distance (mile)
Dbl. Speed(mile/hour)
10 20 30 40 50 60 70
minimum
maximum

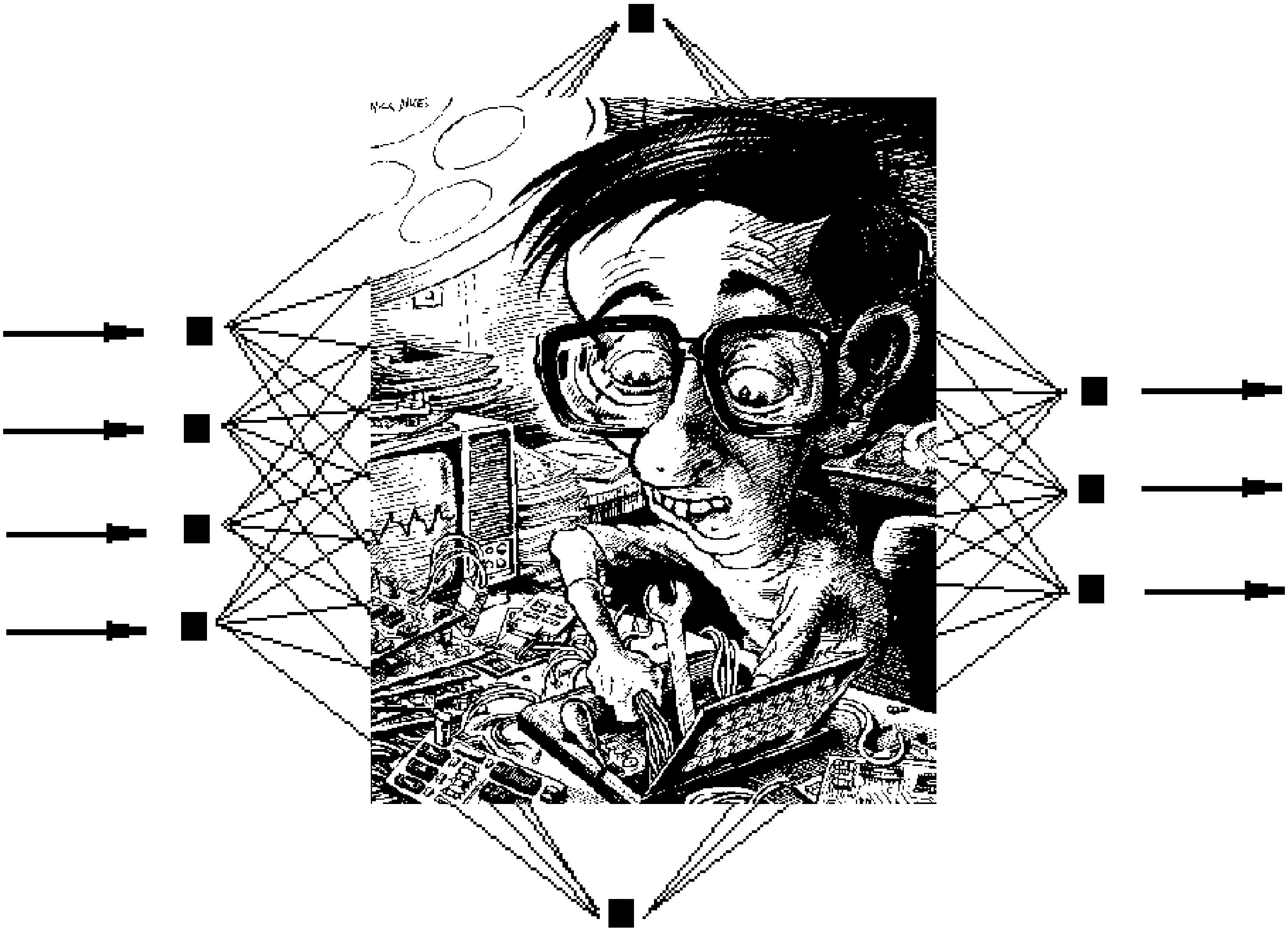
Constraints on Prediction Procedues

- Handle missing data
- Robust to flawed data
- Real time predictions

Attempt to model the dynamics



Attempt via machine learning

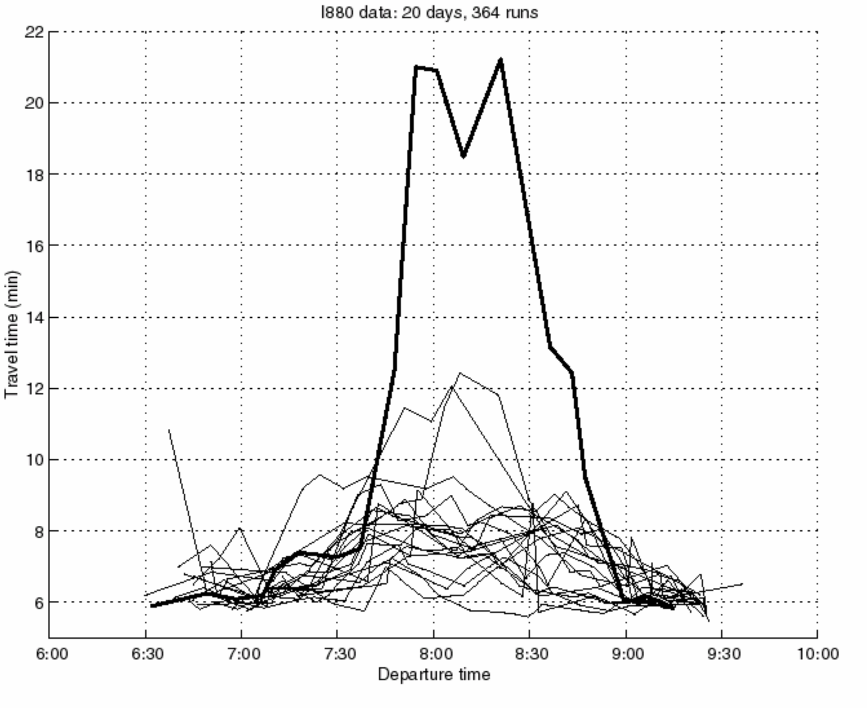


“Automate knowledge management using intelligent agents”

Predictions based on the travel-time curves

Nearest neighbors

Low-rank approximations



Old Friend: Linear Regression

$T(t)$: travel time for trip departing at time t

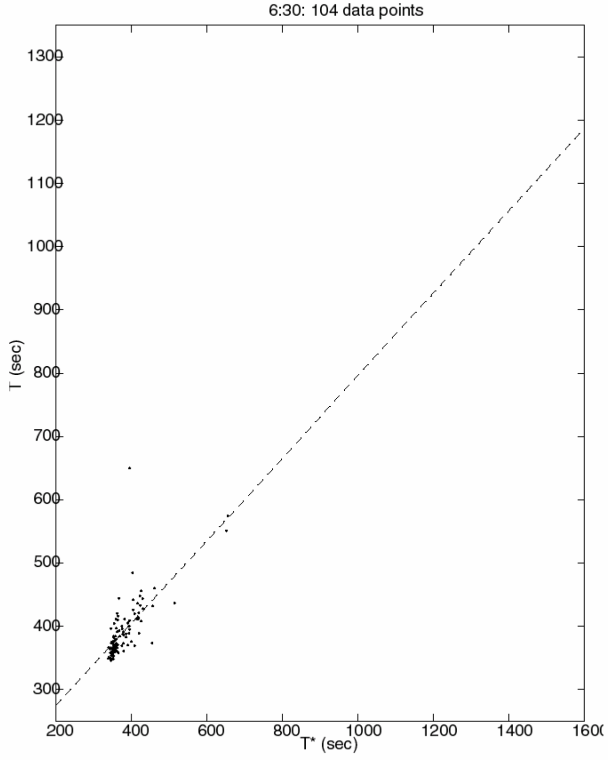
$T^*(t)$: travel time for trip departing at time t if the current state of the freeway were to remain unchanged

To predict $T(t+\Delta)$ from loop detector data up to time t, we

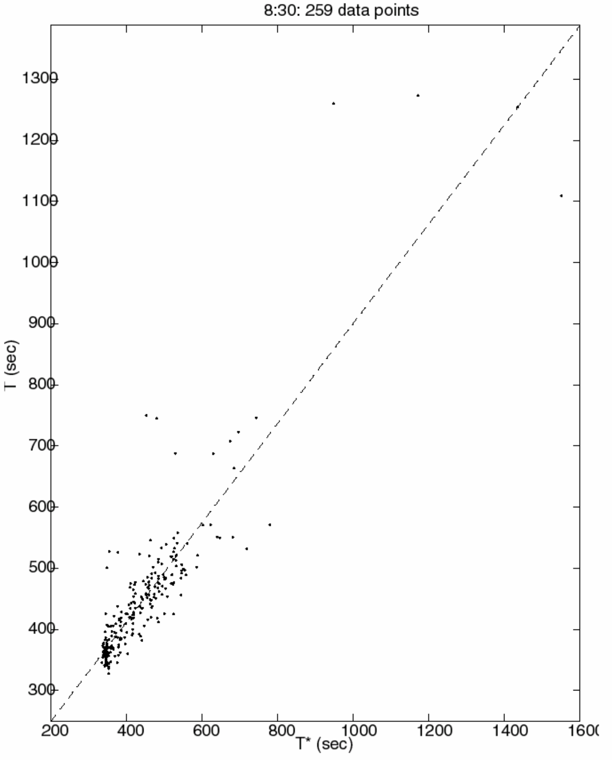
regress $T(t+\Delta)$ on $T^*(t)$

Example

6:30 am



8:30 am



$$T(t+\Delta) = \alpha(t,\Delta) + \beta(t,\Delta)T^{*}(t) + \varepsilon$$

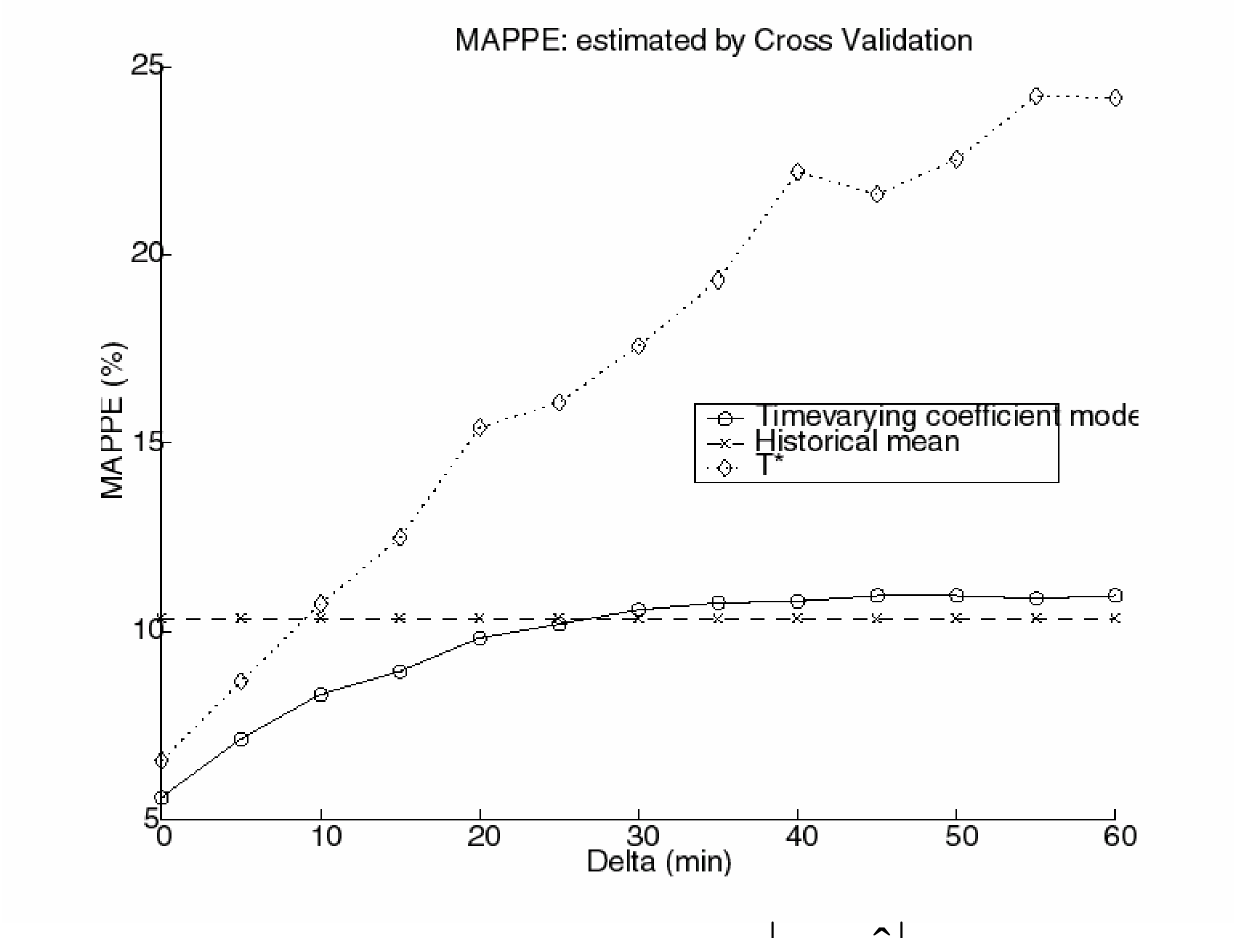
Coefficients fit by minimizing

$$\sum_n \left[T(t_n) - \alpha(t-\Delta,\Delta) - \beta(t-\Delta,\Delta)T^*(t-\Delta)\right]^2 w(t-t_n)$$

Note:

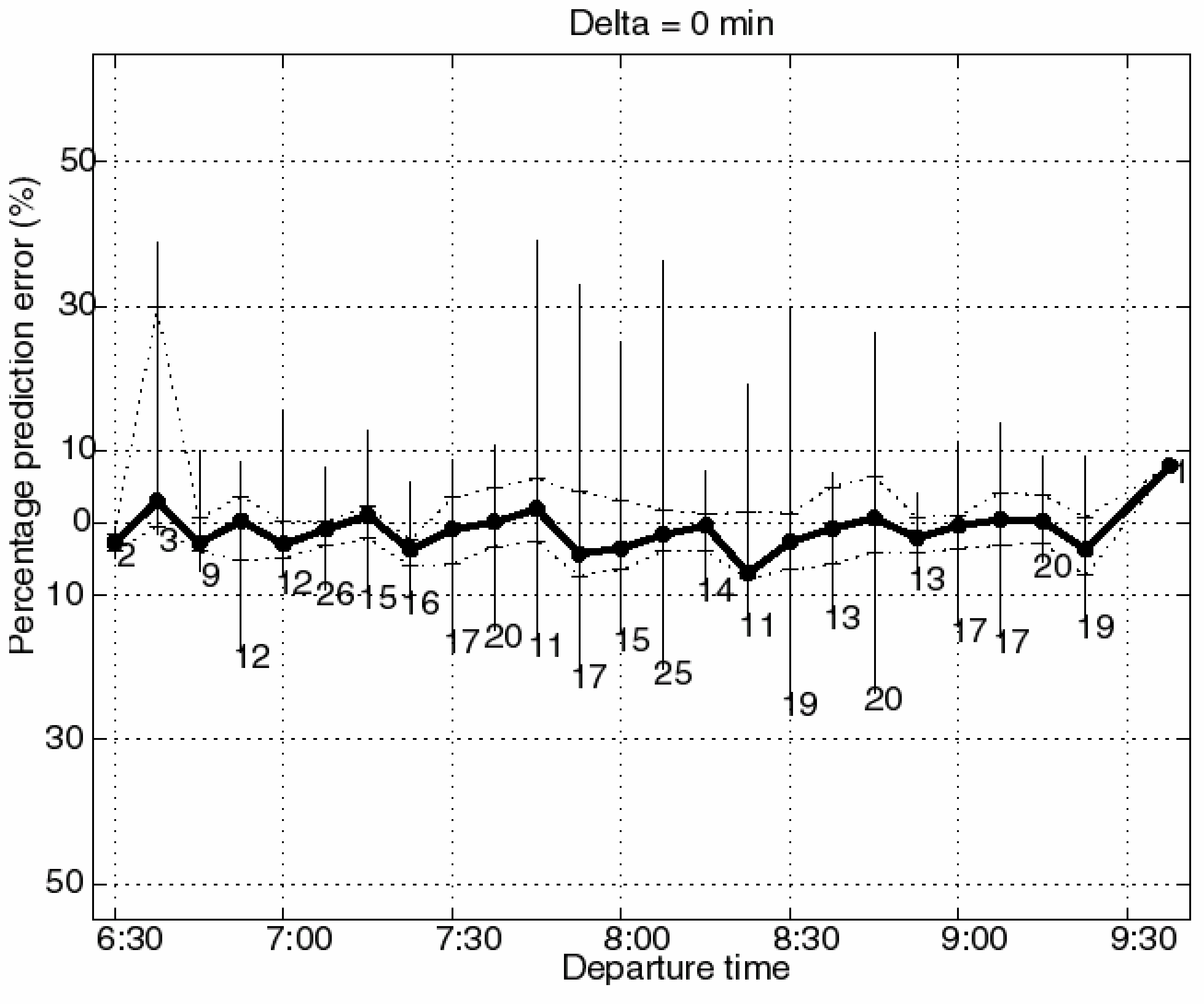
- Regression to the mean
- A “varying coefficient model” (Hastie & Tibshirani)
- Easy to robustify
- Missing data handled naturally
- Fit offline and store coefficients for fast online predictions

Pooling errors over all times of day

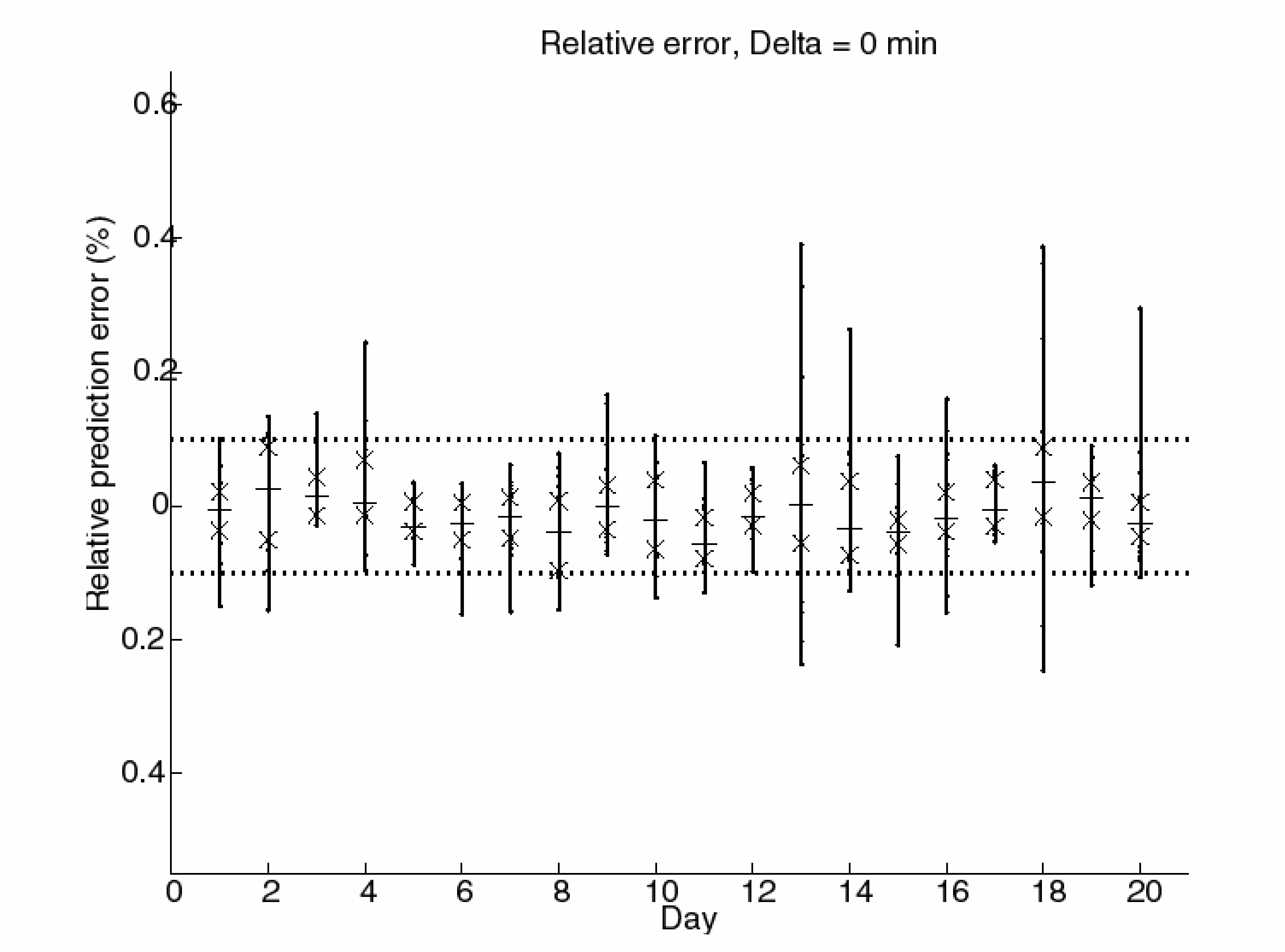


$$MAPPE = Average\left|\frac{T - \hat{T}}{T}\right|$$

Error and Departure Time

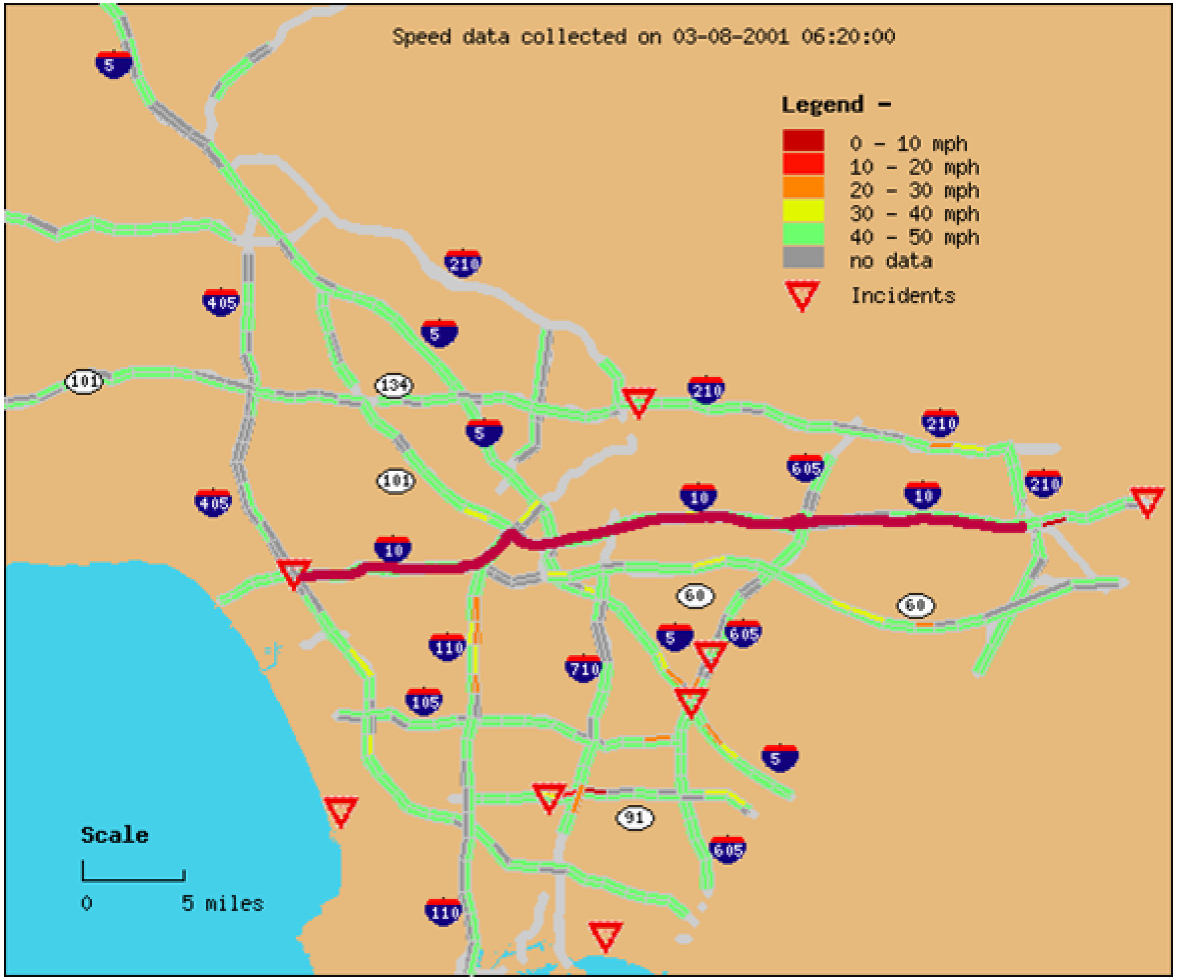


Error by Day

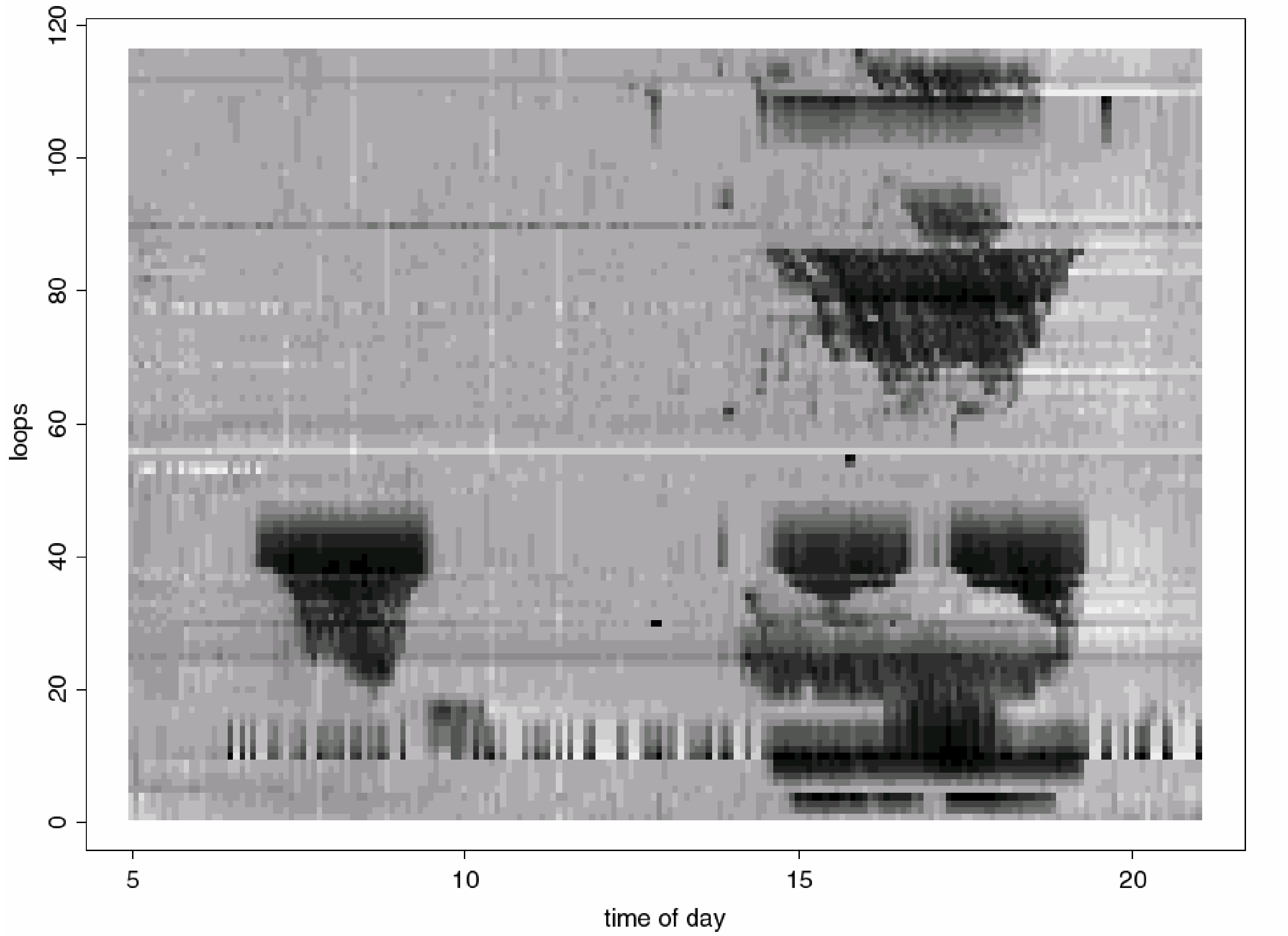


Relative error, Delta = 0 min
Relative prediction error (%)
0.6
0.4
0.2
0
0.2
0.4
0
2
4
6
8
10
12
14
16
18
20
Day

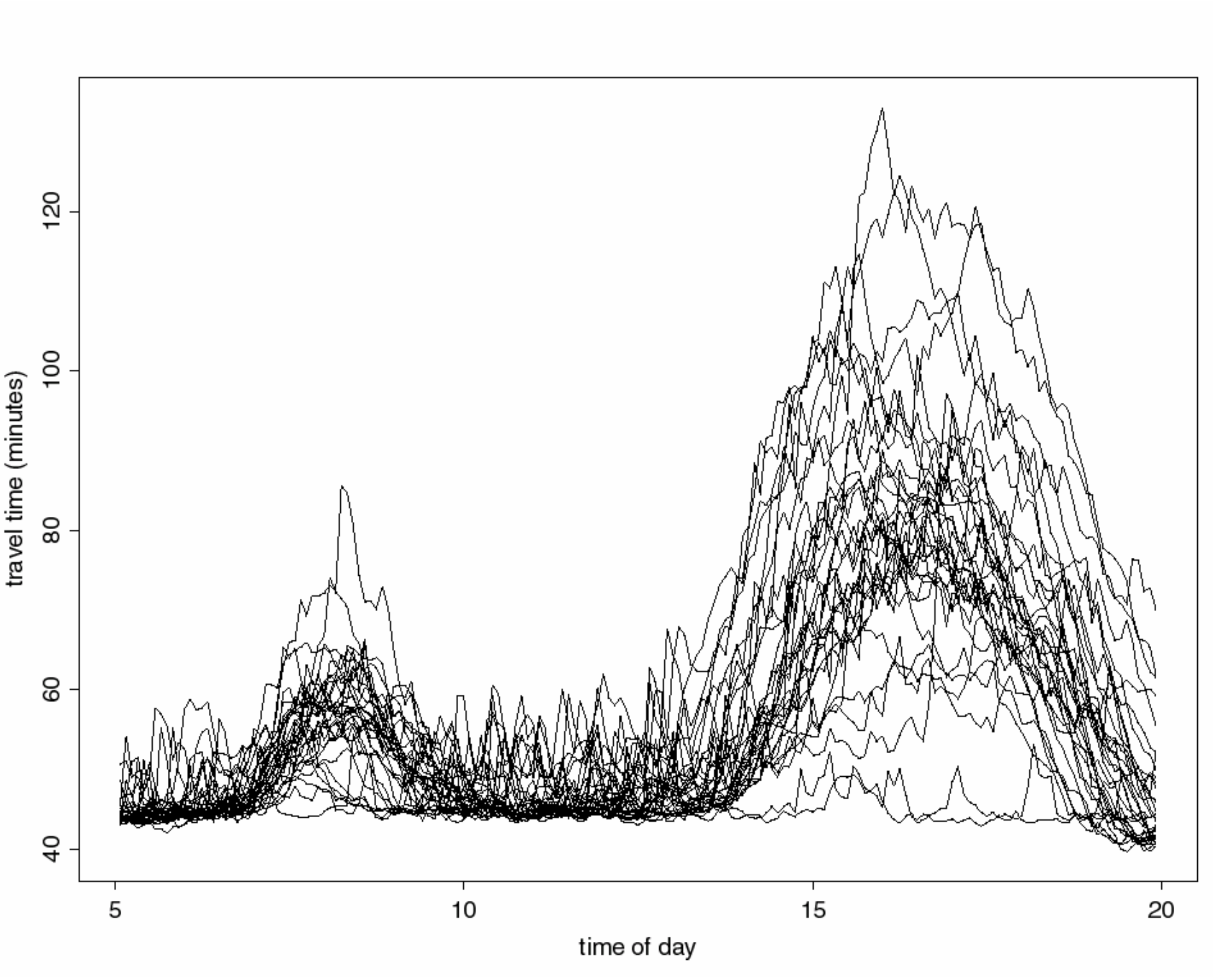
Example: I-10


Speed data collected on 03-08-2001 06:20:00
Legend -
0 - 10 mph
10 - 20 mph
20 - 30 mph
30 - 40 mph
40 - 50 mph
no data
Incidents
Scale
0
5 miles
5
210
405
5
101
134
210
5
210
605
210
101
10
10
405
10
60
60
5
605
110
710
105
5
91
605
110

Velocity Field Portrayed by Loops

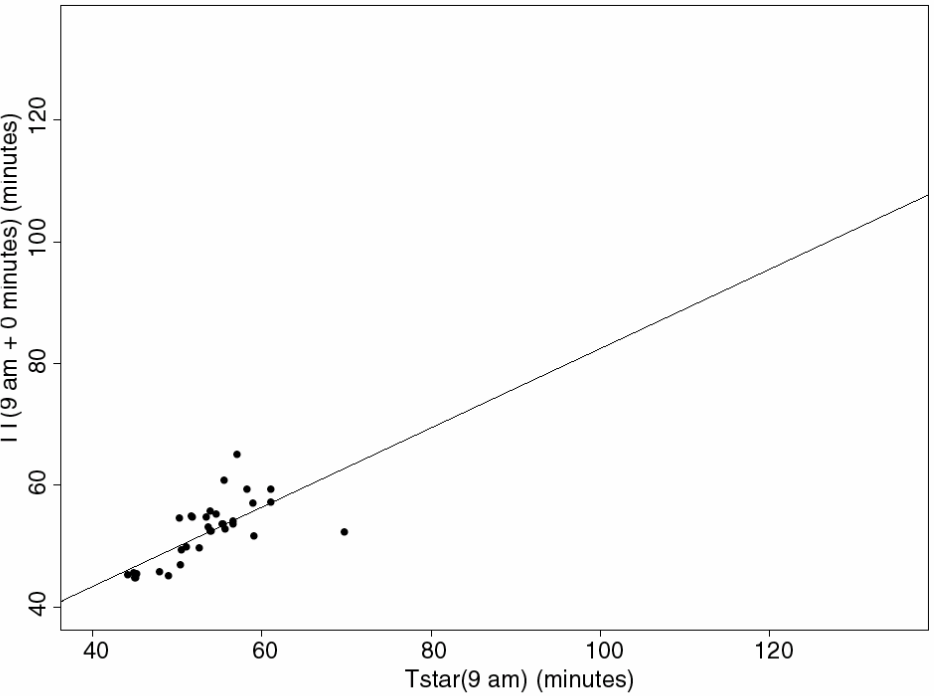


Daily Travel Time Curves

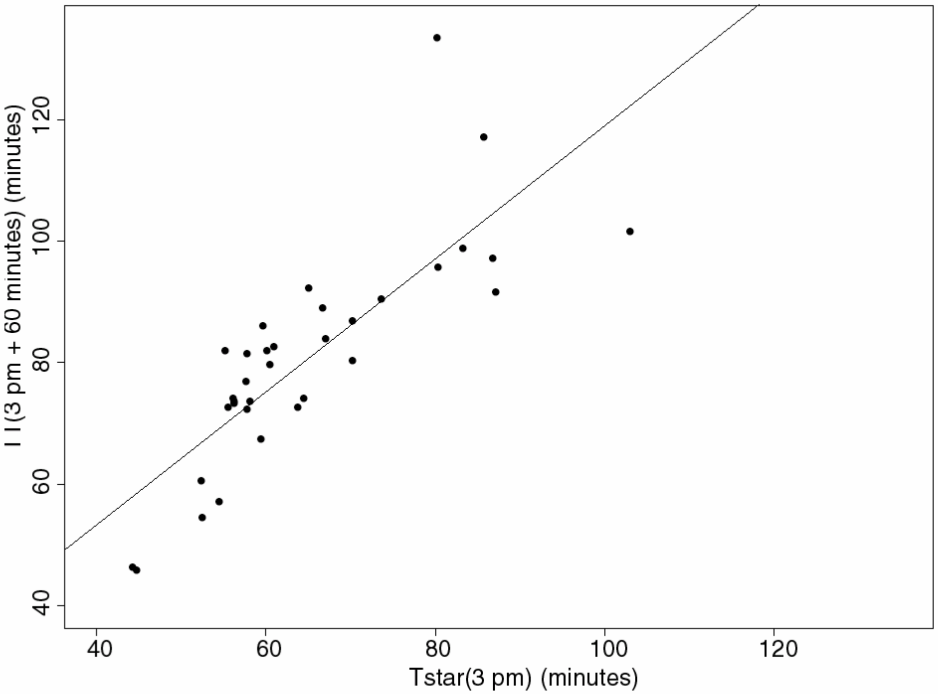


T versus T*

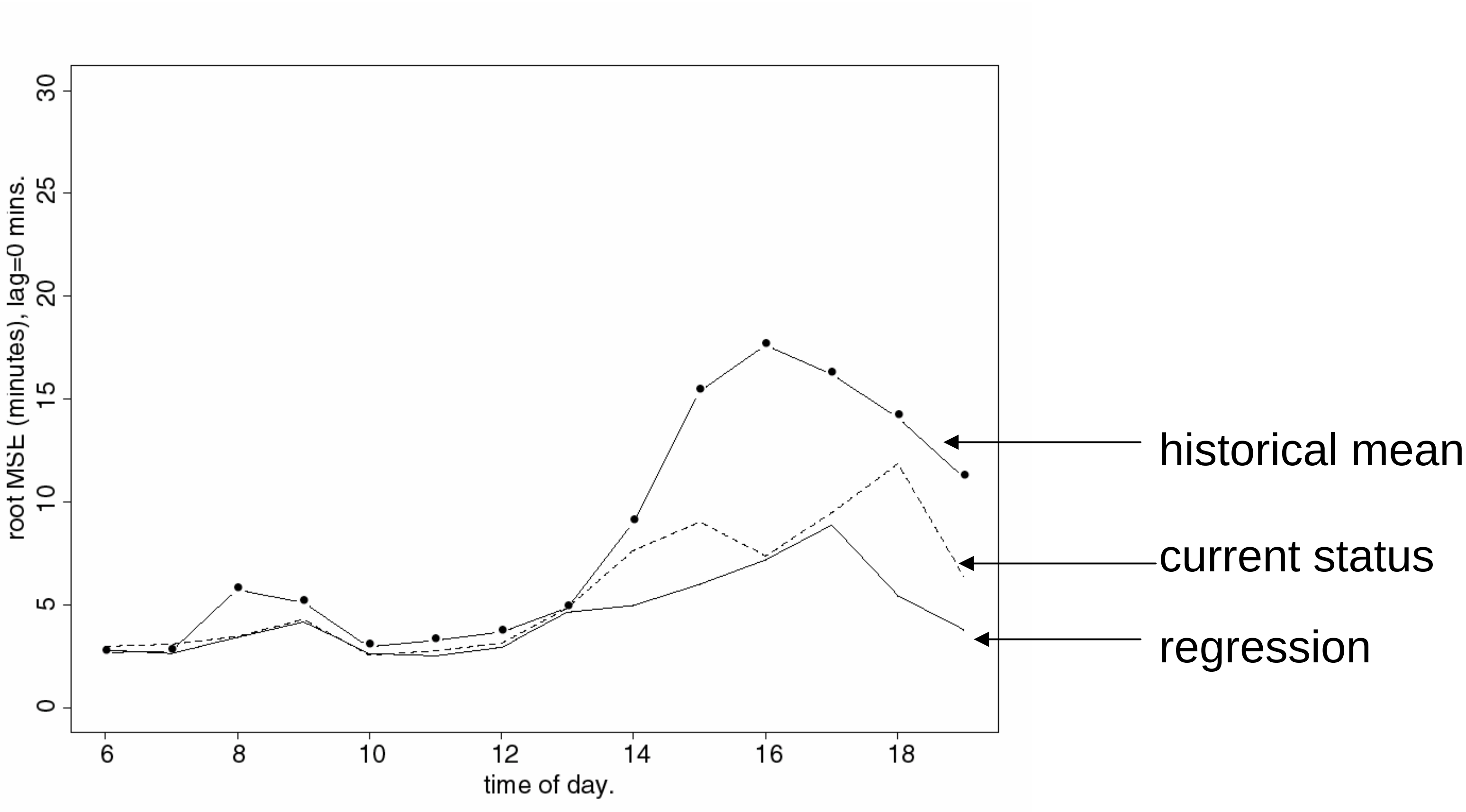
9 am Δ=0

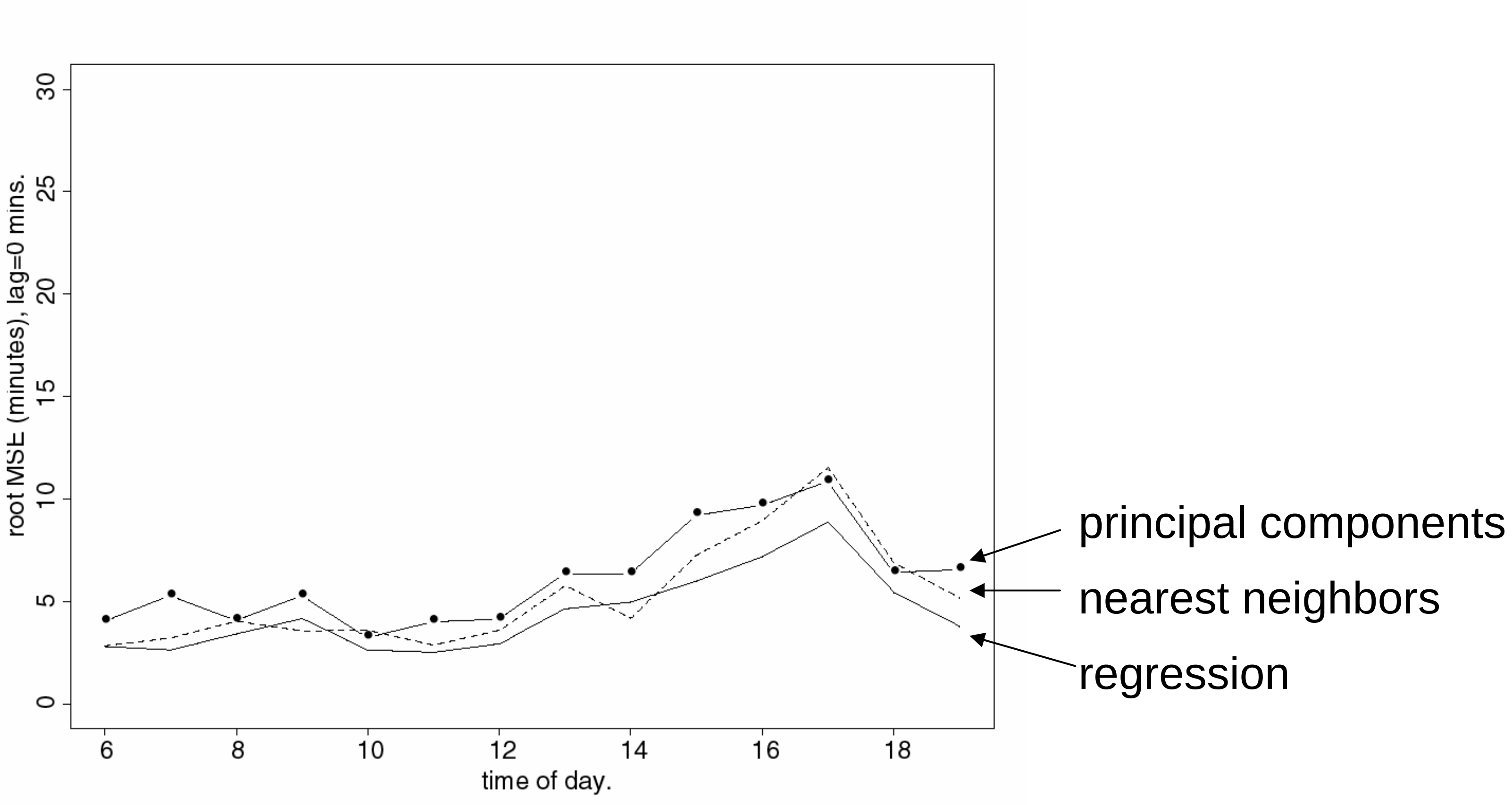


3 pm Δ=60

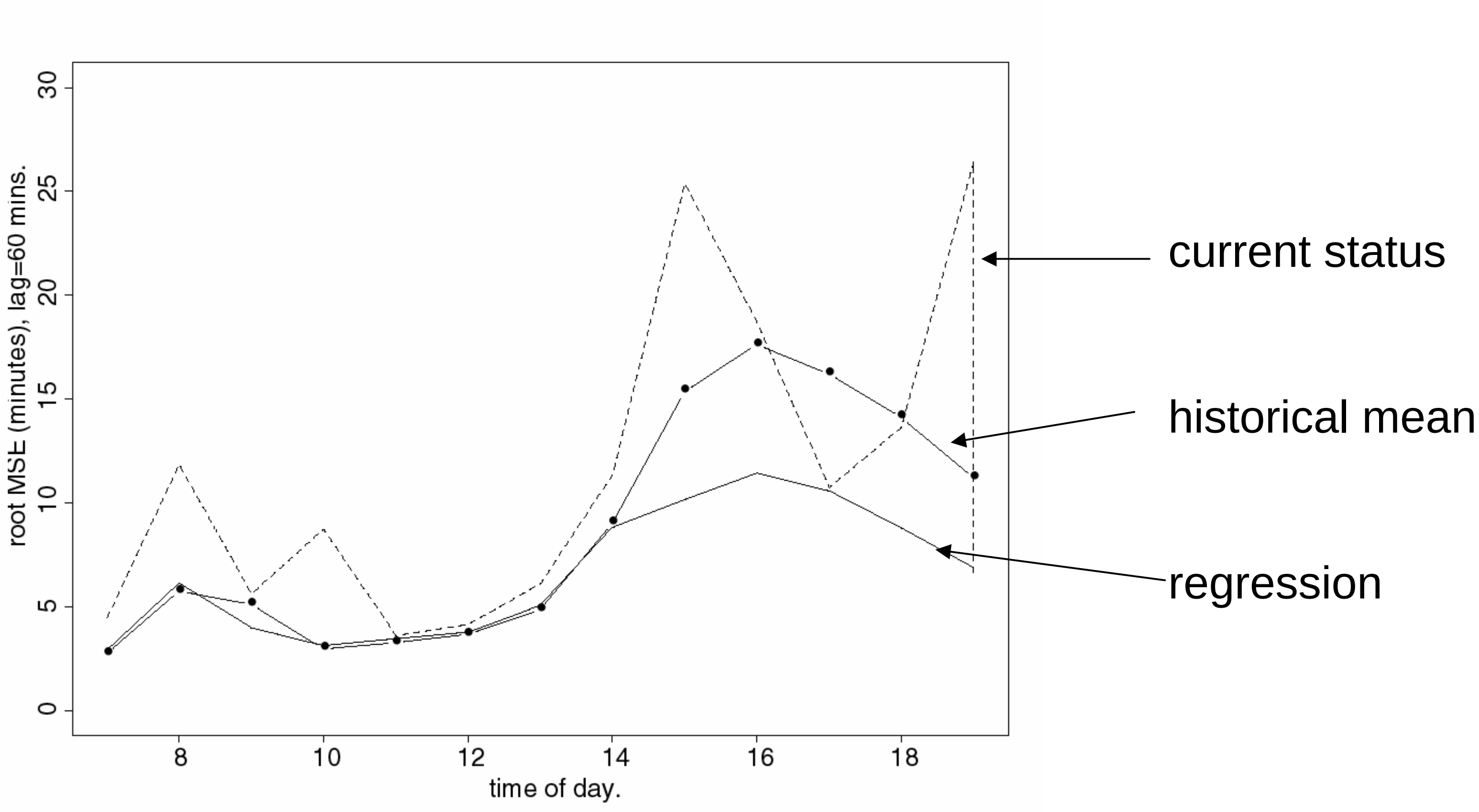


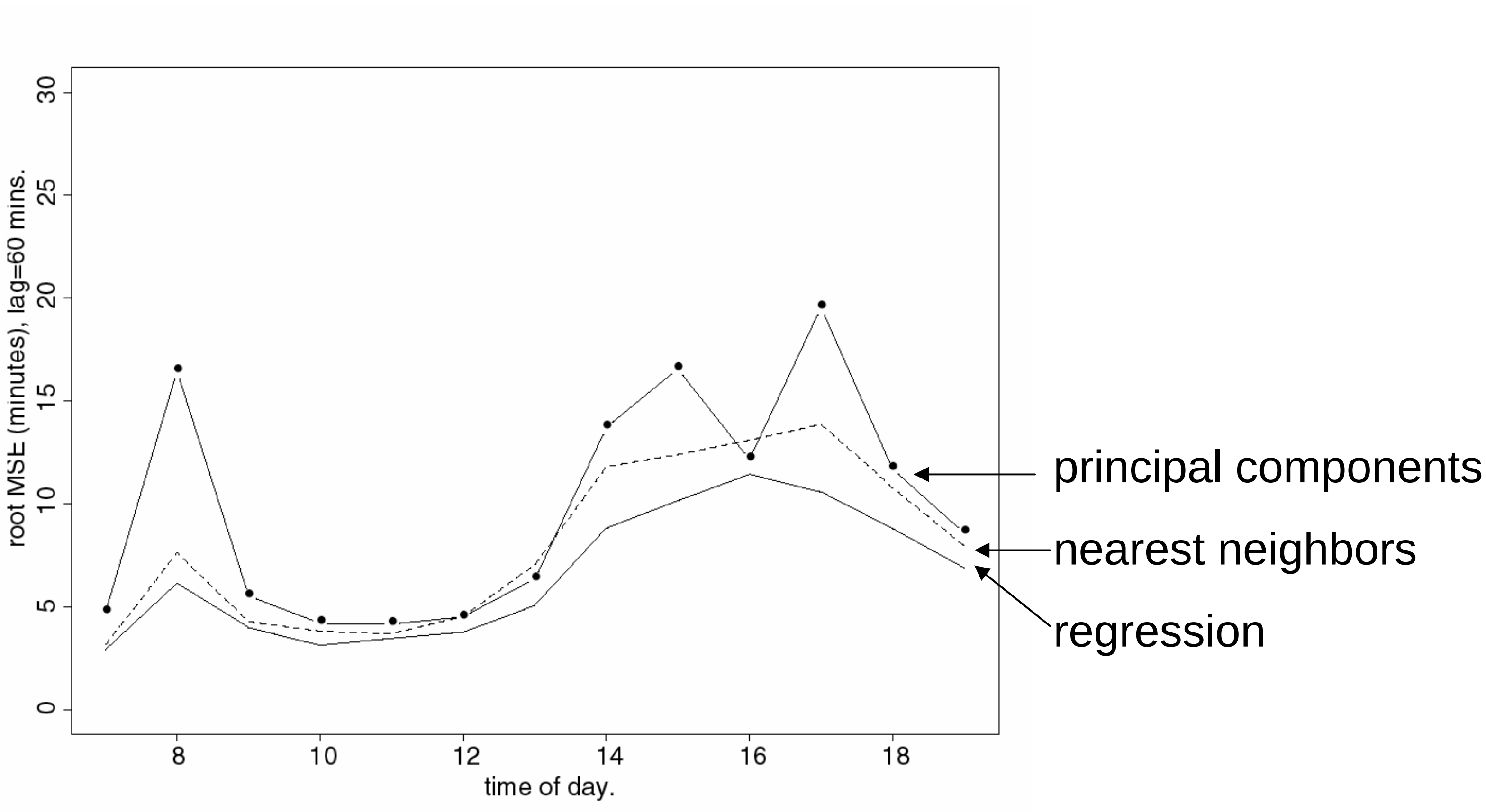
Comparison of predictors: Δ=0




root MSE (minutes), lag=0 mins.
0
5
10
15
20
25
30
6
8
10
12
14
16
18
time of day.
principal components
nearest neighbors
regression

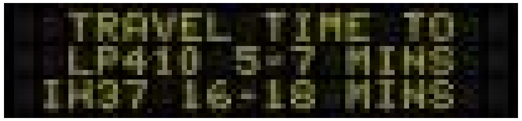
Comparison: $\Delta = 60$



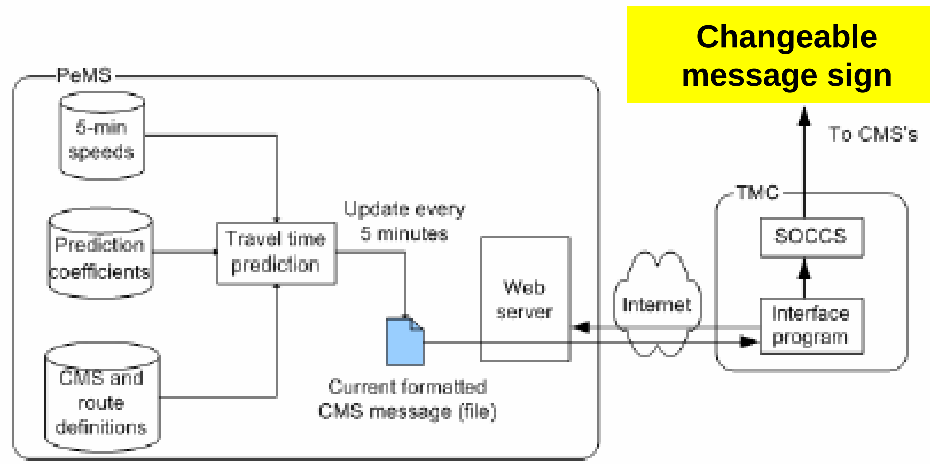


root MSE (minutes), lag=60 mins.
0
5
10
15
20
25
30
8
10
12
14
16
18
time of day.
principal components
nearest neighbors
regression

Example of Use: Changeable message signs can give travelers real-time information



In San Diego, there are two alternate north-south routes. Travelers could be advised by changeable message signs which route has the shortest estimated travel time.



Sometimes one route is faster and sometimes the other is

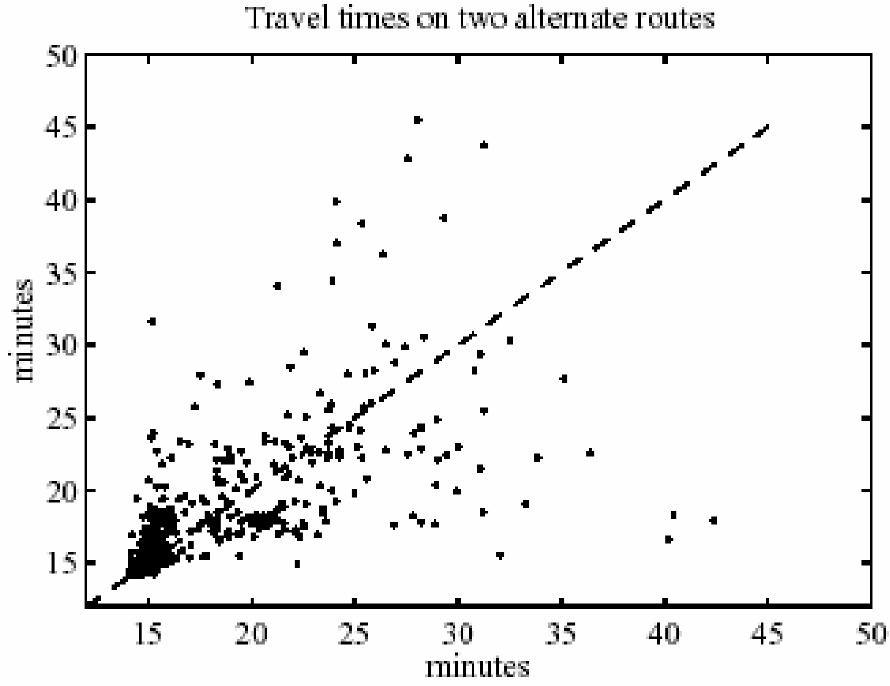
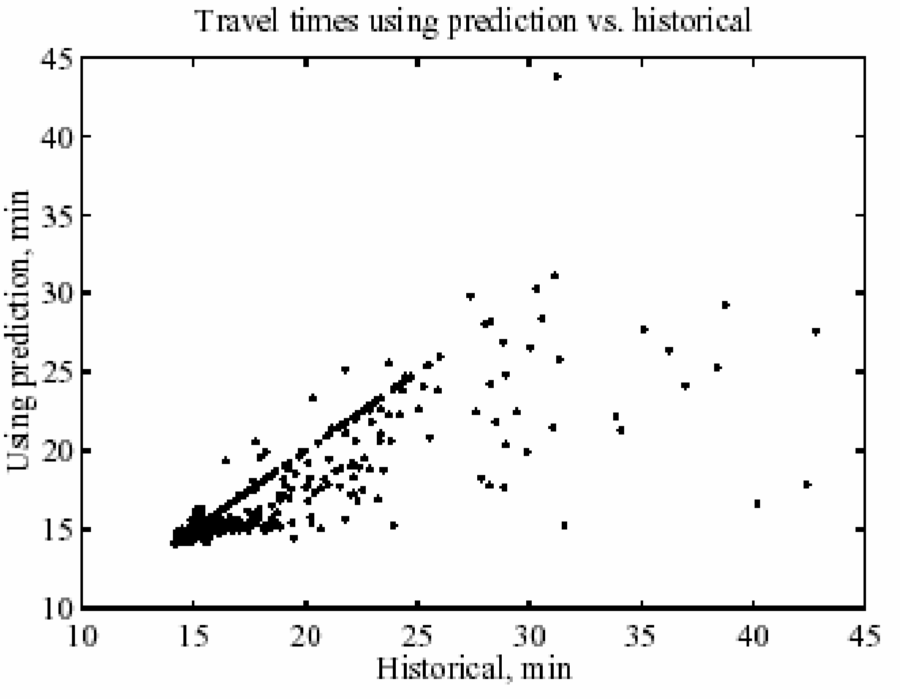
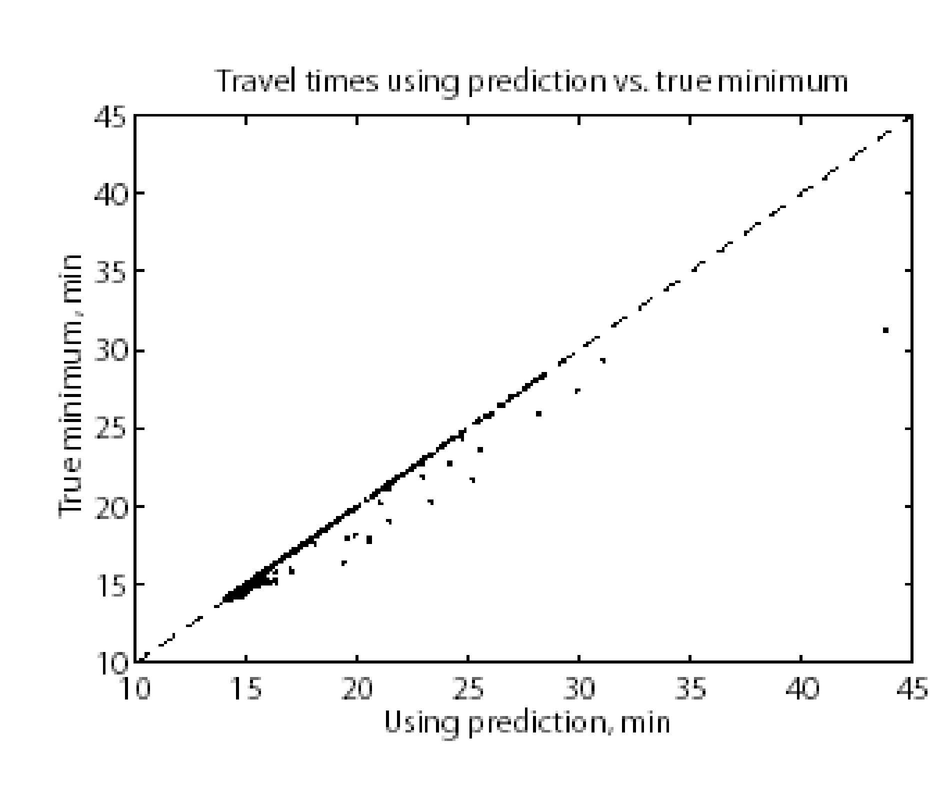


FIGURE 1 Travel times on routes 1 and 2.

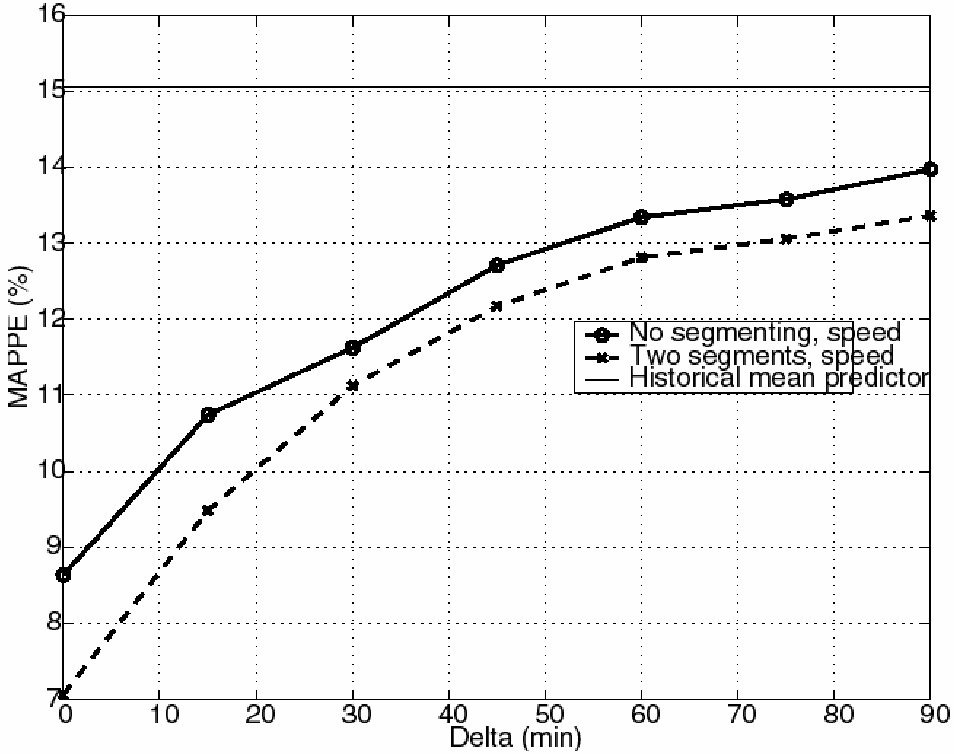
Prediction gives better travel times than using only historical average performance to choose route



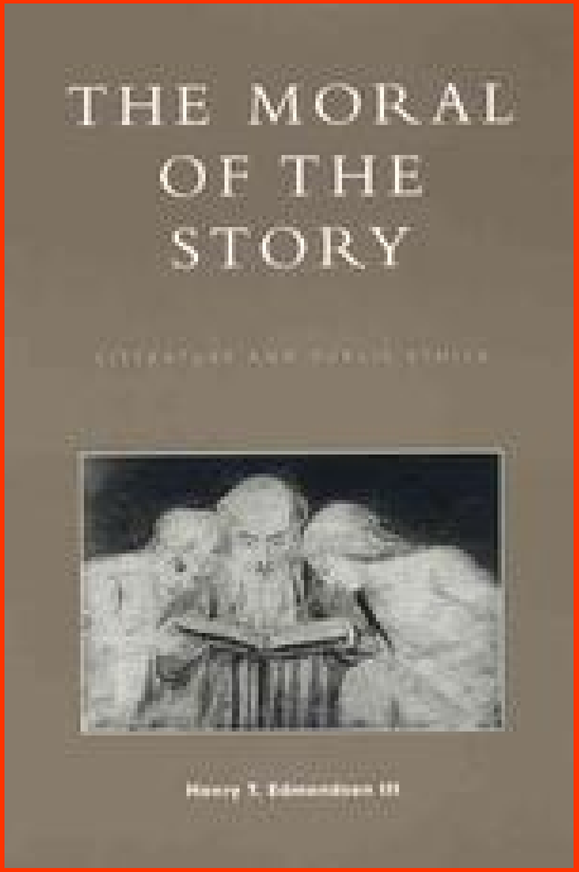
Travel times using predictions are nearly as good as the travel times using the route that is actually the best (but knowable only by an oracle)



Segmentation



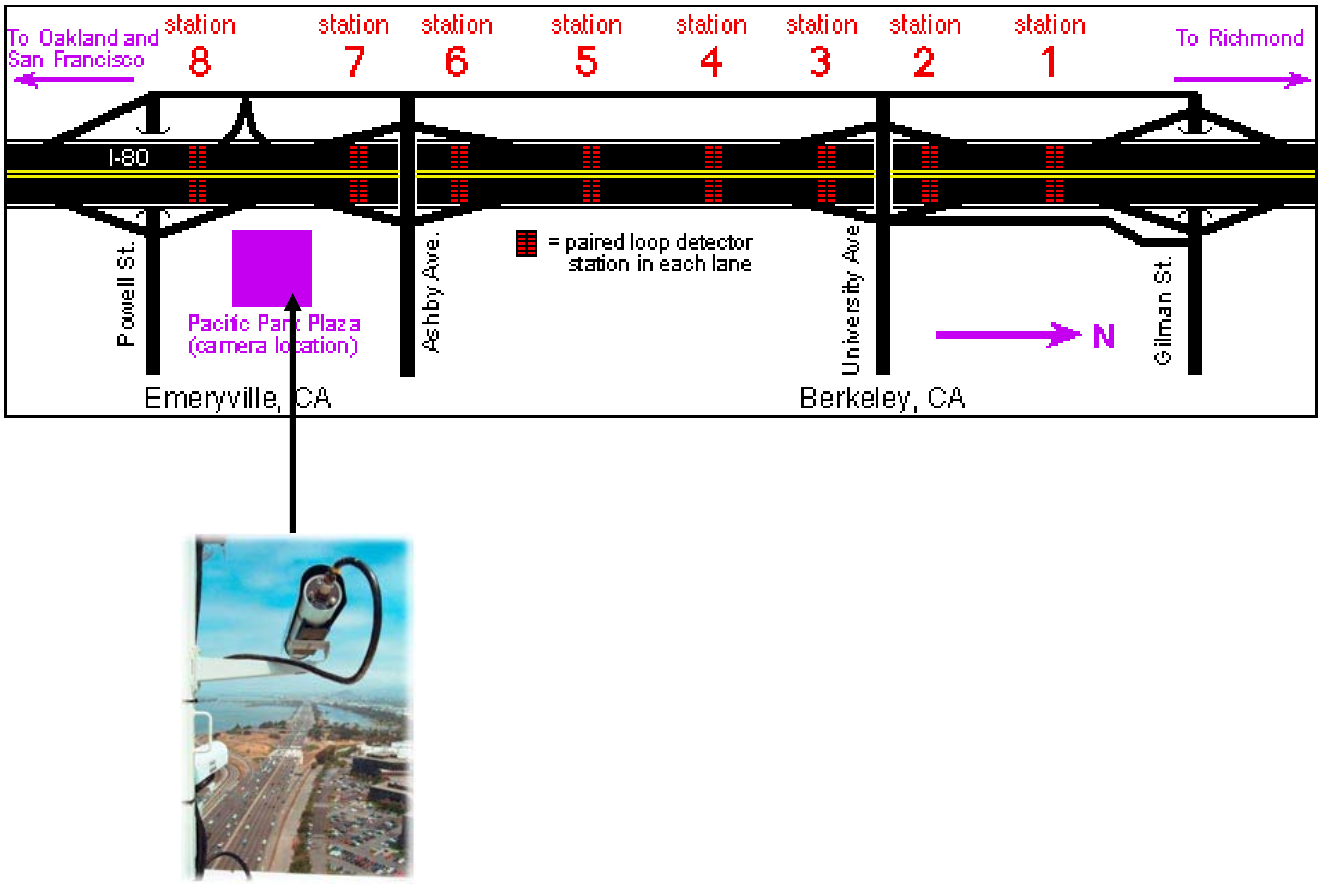
$$\hat{T}_{ABC}(t) = \hat{T}_{AB}(t) + \hat{T}_{BC}\left(t + \hat{T}_{AB}(t)\right)$$



To predict a functional of a complex system, it may not pay to try to model the whole system. Predicting that functional by others, selectived by intuition and data analysis, may work

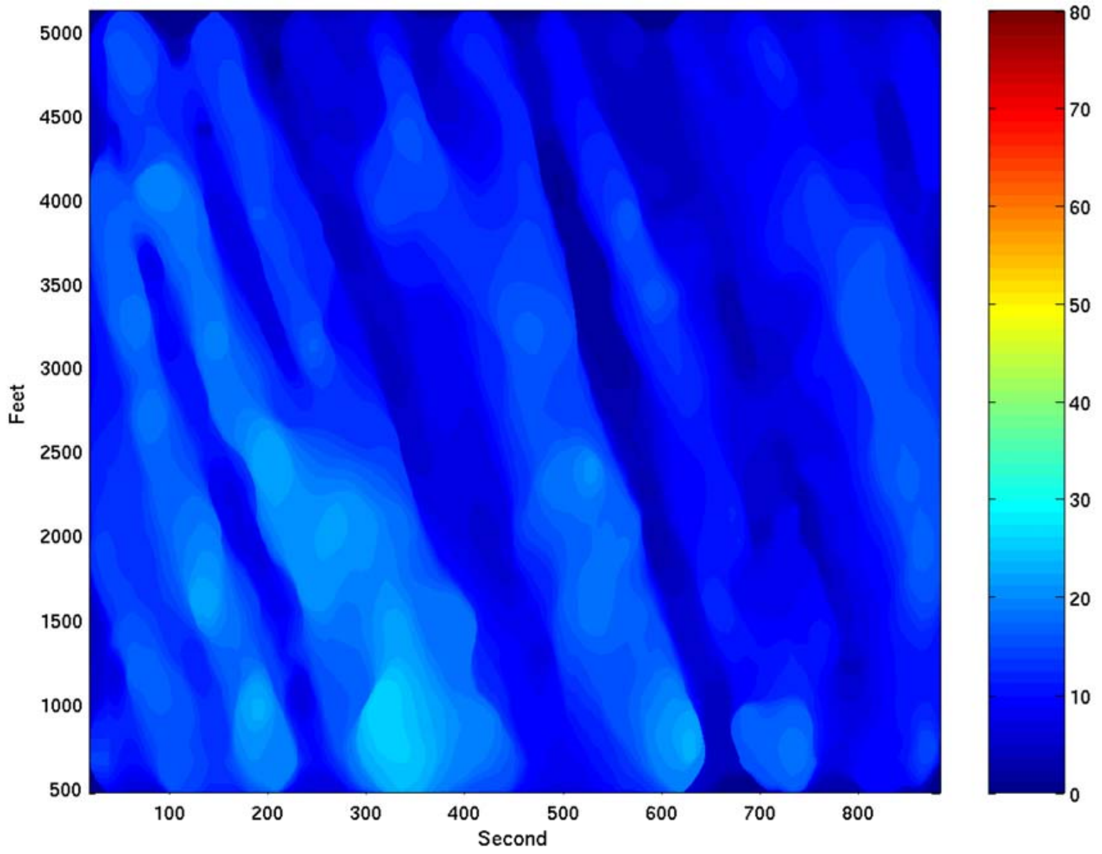
Video Project

Berkeley Highway Laboratory



I-80: the movie

Estimate of west bound velocity field, third lane



Comparison of estimate with loop detectors