

Living with and loving transportation technologies

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[Research sponsors: NSF, NCSA, FHWA UTC, ICT/IDOT, UIUC COE and CEE]

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Some *critical issues* in transportation

- safety
- congestion
- energy & environment
- accessibility
- aging infrastructure
- etc...

[Transportation Research Board of the National Academies 2009]
Schrank and Lomax, Texas Transportation Institute 2009; Chicago
MPC 2010, fufotos 2011]

How do we address these challenges?

- To make progress, we need a tighter integration between our **physical transportation infrastructure** and our **computing infrastructure**

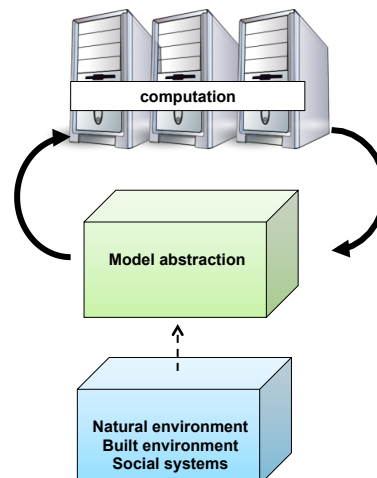


“All models are wrong, but some are useful” – G. Box

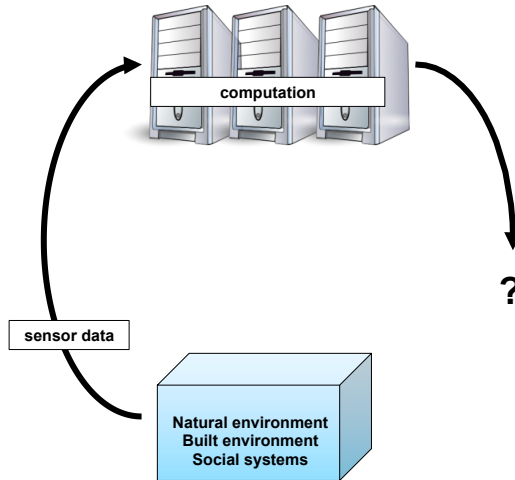


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- **mathematical model**
 - represents the physical environment
- **requires (but possibly unknown)**
 - initial conditions
 - boundary conditions
 - parameters

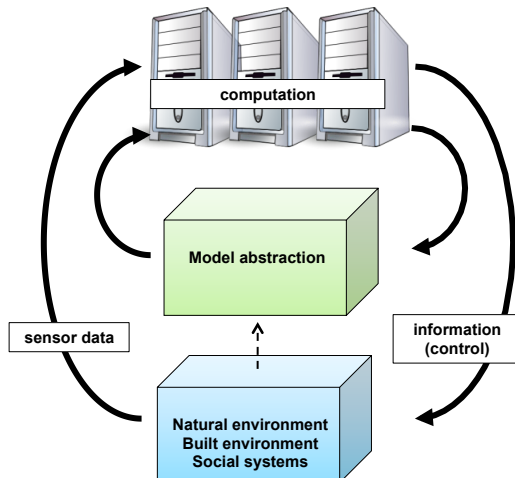


“All models are wrong, and increasingly you can succeed without them” - C. Anderson (~P. Norvig)



What happens when you combine the two?

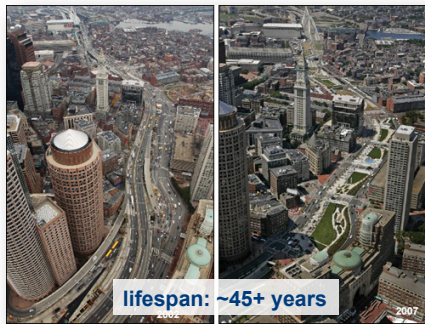
- The sciences of “smart”
 - Estimation
 - Prediction
 - Control
 - Optimization
 - etc.
- Accounts for
 - Modeling errors
 - Uncertain inputs
 - Noisy measurements



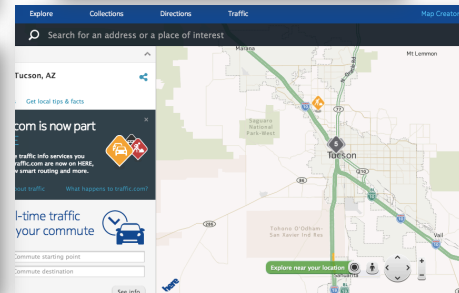
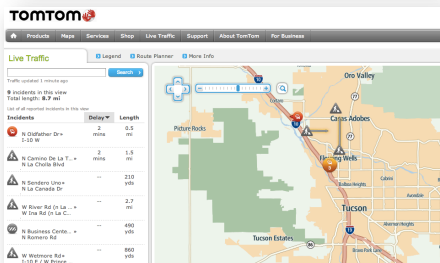
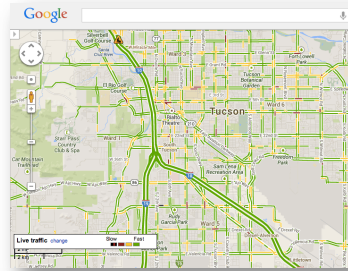
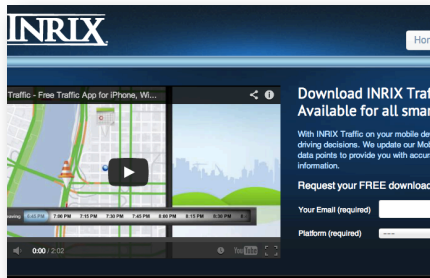
Transportation technology timescales

In 2007...

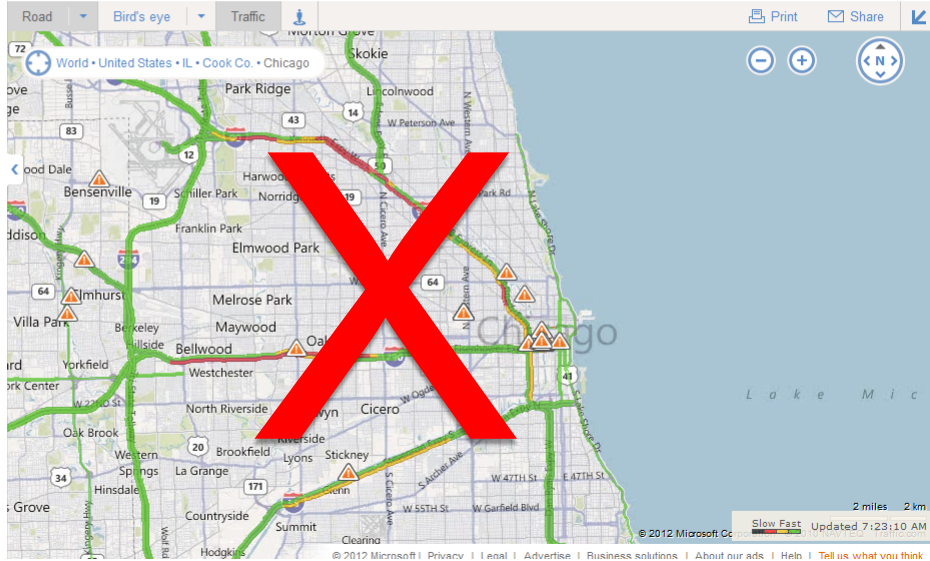
- Best selling phone: Nokia 1200
- Best selling car: Toyota Camry
- Biggest infrastructure: Big Dig, Boston



Changing who collects traffic information...



And changing how we consume it



Until 2020 (+)

AutoGuide
.com

New Cars Used Cars Car Reviews Tips and A

Video Auto Insurance Compare Cars Spy Photos

Home / Auto News / News article: BMW Targets 2020 for Self-Driving Cars

Ford Furthers Open-

BMW Targets 2020 for Self-Driving Cars

Stephen Elmer | Feb 26, 10:59 AM

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Uber Teams Up With Carnegie Mellon on Self-Driving Car Research

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CNET / Reviews / The Car Tech Blog / GM: Expect self-driving vehicles by 2020

GM: Expect self-driving vehicles by 2020

Self-driving vehicles may seem cutting-edge, but they could be on the road by then, says GM CEO. [View Full Story](#)



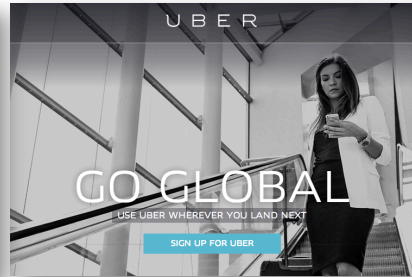
Google planning 'robo taxi' fleet



Technology already enables “brain off” driving



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Critical issues in smart transportation: *privacy*



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SCIENTIFIC
REPORTS



Unique in the Crowd: The privacy bounds of human mobility

SUBJECT AREAS:
APPLIED PHYSICS

Yves-Alexandre de Montjoye^{1,2}, César A. Hidalgo^{1,3,4}, Michel Verleysen² & Vincent D. Blondel^{2,5}

- Hugely valuable for travel demand modeling, but
- 4 points (tower location + time) uniquely characterize mobility traces of 95% of cell phone users

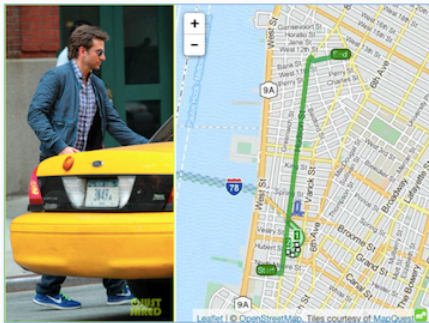
[Alexandre de Montjoye et al. 2013]

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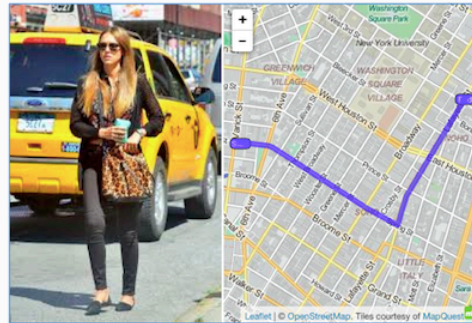
Privacy attack: "Riding with the stars"



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Bradley Cooper (Click to Explore)



Jessica Alba (Click to Explore)

- **Main idea:** identify celebrity trips by combining publically available (time-stamped and geo-tagged) photos with public taxi data
- **Solution:** *Differential privacy* – guarantees privacy protection.

[A. Tockar, Neustar Research, 2014]

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Critical issues in smart transportation: *security*



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- The transportation system is a computer. It comes with all the *pros* and *cons* of your computer.
- Vulnerabilities exist today



ODB II port attack



Hackers Alter Road Signs
Portable changeable message sign attack

[Koscher et al. 2010]

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Security attack: “Green lights forever”



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- Network protocols are accessible to attackers due to the lack of encryption.
- Devices on the network lack secure authentication due to the use of default usernames and passwords.
- The traffic controller is vulnerable to known exploits.



TODO when you get home:

- Change default device credentials (e.g. passwords).
- Enable encryption (WPA2) on wireless radios in the field.
- Update controller firmware

[Ghena et al., 2014]

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Critical issues in smart transportation: *authentication and control*



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- How do you authenticate crowd sourced data?
- Recognizing information is a form of control



“In the future, when 10% of drivers use TomTom’s HD Traffic... our road networks will start to balance out and we will reduce traffic congestion for everyone.”

[TomTom. 2014]

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GPS signals are not authenticated

- Your GPS receiver can be spoofed
- Huge risks for
 - Navigation (drivers and drones)
 - Precise timing
 - Pay per mile
 - etc.



FAST FEED 160 SHARES

HIGH-TECH PIRATES: RESEARCHERS HACK A YACHT VIA GPS

UNDETECTED BY THE SHIP'S CREW, THE 213-FOOT VESSEL VEERED OFF COURSE AFTER RESEARCHERS DEPLOYED A CUSTOM-MADE SPOOFING DEVICE ON THE GPS SYSTEM.

BY ADDY DUGDALE

Using a homemade spoofing device small enough to be concealed in a suitcase, researchers from the University of Texas managed to hack the GPS of a yacht in the Mediterranean and bring it off its programmed course. Professor Todd Humphreys, assistant professor of the Department of Aerospace Engineering and Engineering Mechanics at UT's Cockrell School of Engineering, said, "the ship actually turned and we could all feel it, but the chart display and the crew only saw a straight line."

[T. Humphreys. 2015, L. Heng, D. Work, G. Gao 2014] 17

Designing smart transportation systems

- Need to merge the timescales of internet innovation with the longevity of physical infrastructure
 - Platform for innovation and adaptability
 - Interoperability and portability
- Need reliable smart transportation systems from unreliable components
 - Sensors will fail, will be attacked
 - Computing systems will have bugs and security vulnerabilities

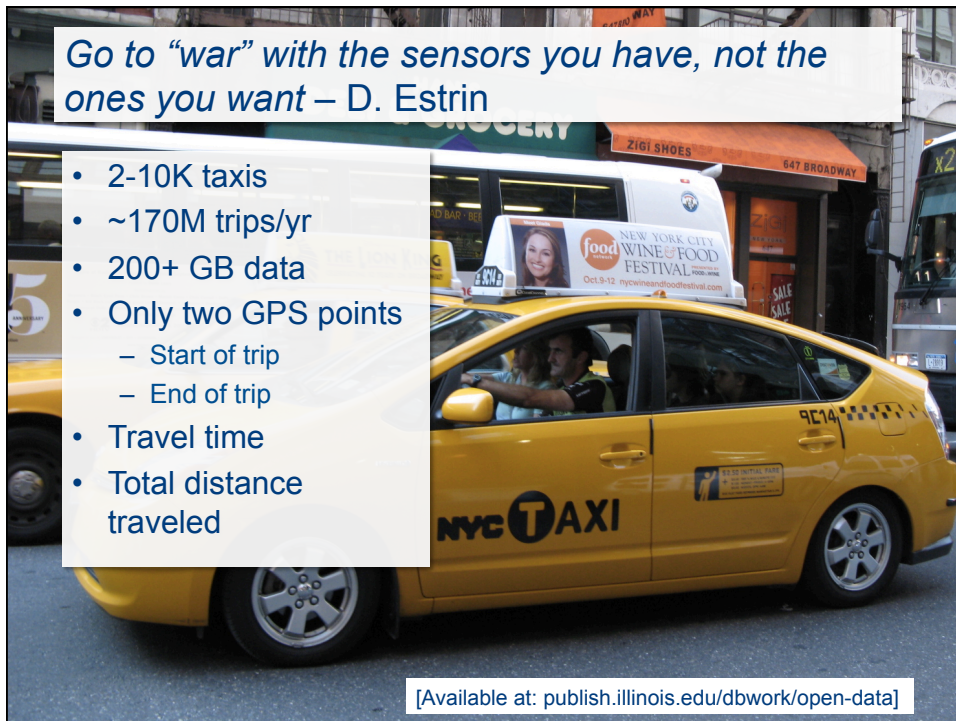
[Cyber Physical Systems Executive Summary 08]

One promising area: big data = digital mud



Go to “war” with the sensors you have, not the ones you want – D. Estrin

- 2-10K taxis
- ~170M trips/yr
- 200+ GB data
- Only two GPS points
 - Start of trip
 - End of trip
- Travel time
- Total distance traveled



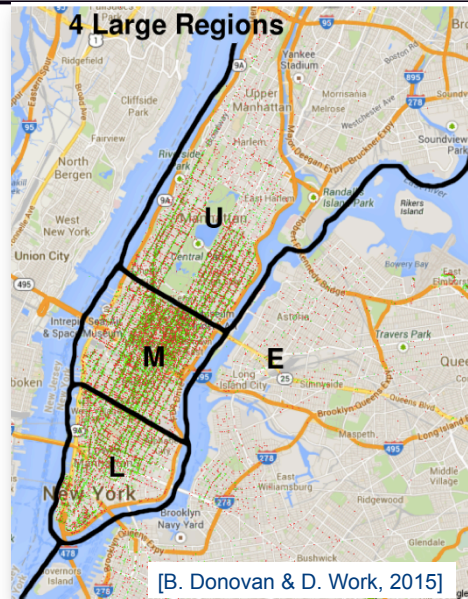
[Available at: publish.illinois.edu/dbwork/open-data]

Spatial discretization



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- Four zones
 - U: Upper Manhattan
 - M: Midtown
 - L: Lower Manhattan
 - E: East of Hudson River
- Generates 16 possible *origin destination* (OD) pairs
- Some OD pairs are connected by critical infrastructure



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Traffic pace



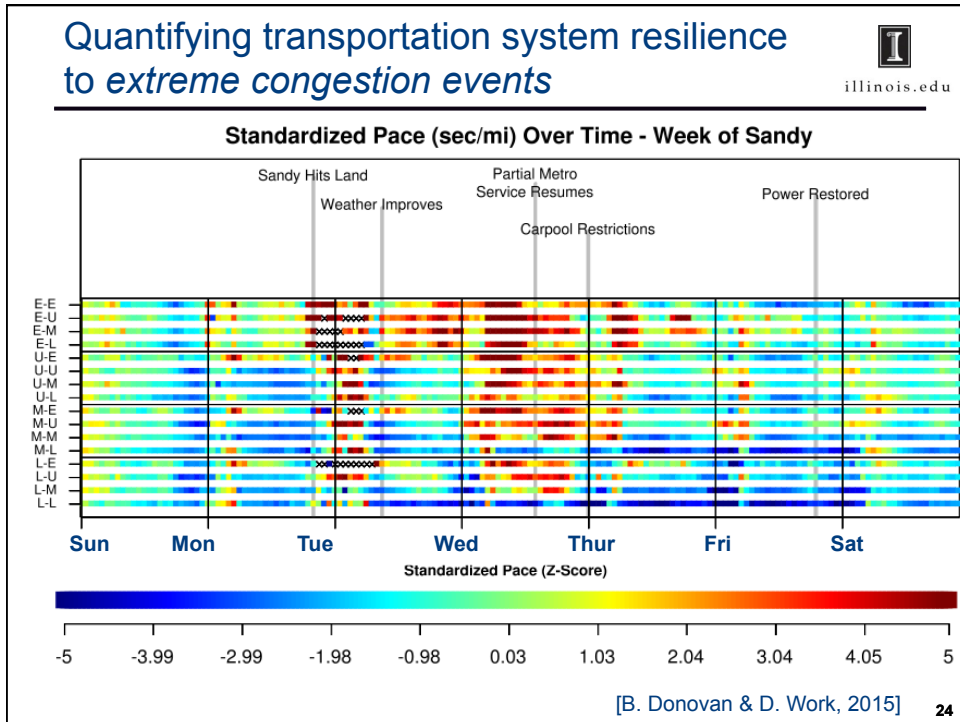
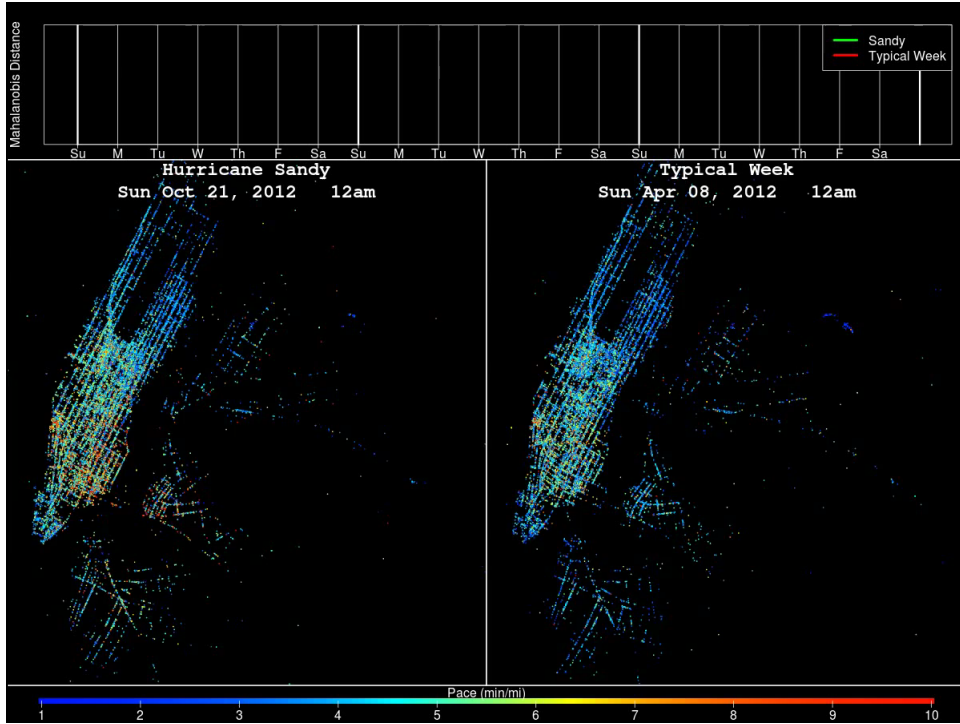
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- Travel times are commonly used to measure performance
- Pace = travel time / distance
 - Pace effectively normalizes against distance
 - Flow of taxis != Flow of all vehicles
- Average pace = 4.6 minutes / mile
 - This varies in different regions
 - Also varies over time



[B. Donovan & D. Work, 2015]

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Long term goal: Improve transportation policy

As Hurricane Season Strengthens, NYC Tells Residents to "Know Your Zone"

BY GRAHAM T. BECK | AUGUST 29, 2014



Find Your Zone **Know the Hazards** **Stay Informed**

[nextcity.org]

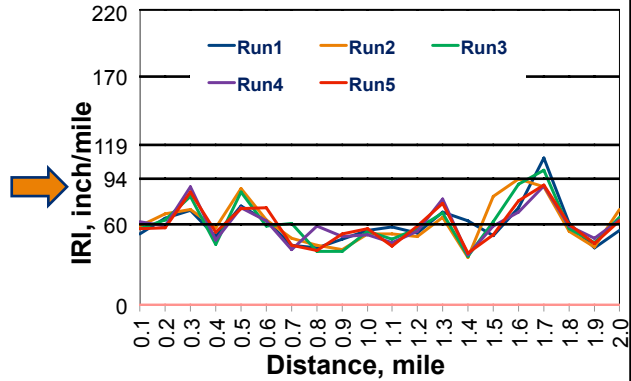
Pavement roughness evaluation via smartphones



[W. Buttlar, S. Islam, W. Vavrik, 2015]

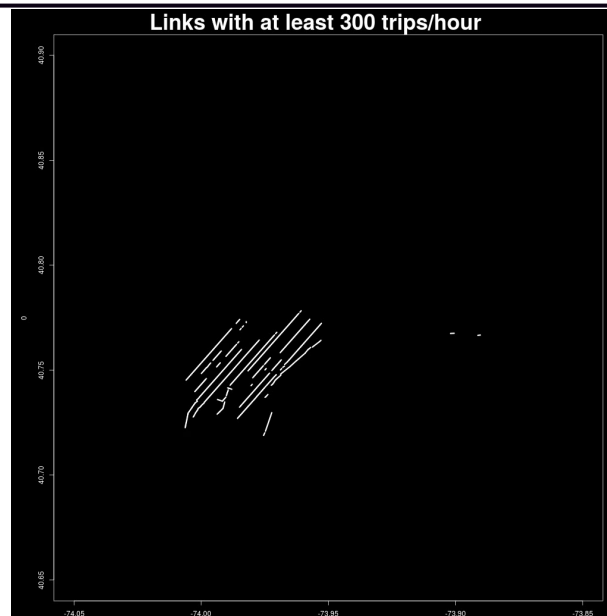
Repeat, e.g., with fleets

- Huge crowd sourced datasets can significantly reduce errors while providing increased coverage



[W. Buttler, S. Islam, W. Vavrik, 2015]

Then scale it: Coverage of 10,000+ taxis



Summary



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- Transportation systems need to get smarter to extract better performance
 - First the phone, then the car, then the infrastructure
- When the system becomes a computer, it has all the benefits and drawbacks of a computer
 - Assume it will be hacked, design against it
 - Bring in the right domain experts to help
- The potential opportunities of technology and transportation systems are just beginning to be explored, big data and cheap computing will help.

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