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Deriving Lane-level Insight from GPS Data: Innovations for Traffic & Autonomous Driving

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HERE Technologies

FRIDAY TRANSPORTATION SEMINAR

Deriving Lane-level Insight from GPS Data: Innovations for Traffic & Autonomous Driving

Portland State UNIVERSITY

April 5, 2019
11:30 AM (PST)

James Fowe, Principal Research Engineer

Here Technologies, USA

Deriving Lane-level Insight from GPS Data
- Innovations for Traffic & Autonomous Driving

This talk will give a high level overview of GPS probes data and navigation systems in general and some leading products from HERE Technologies with the goal of challenging students on the exciting opportunity to advance the field of Intelligent Transportation Systems using location data and applied Machine Learning / AI.

here

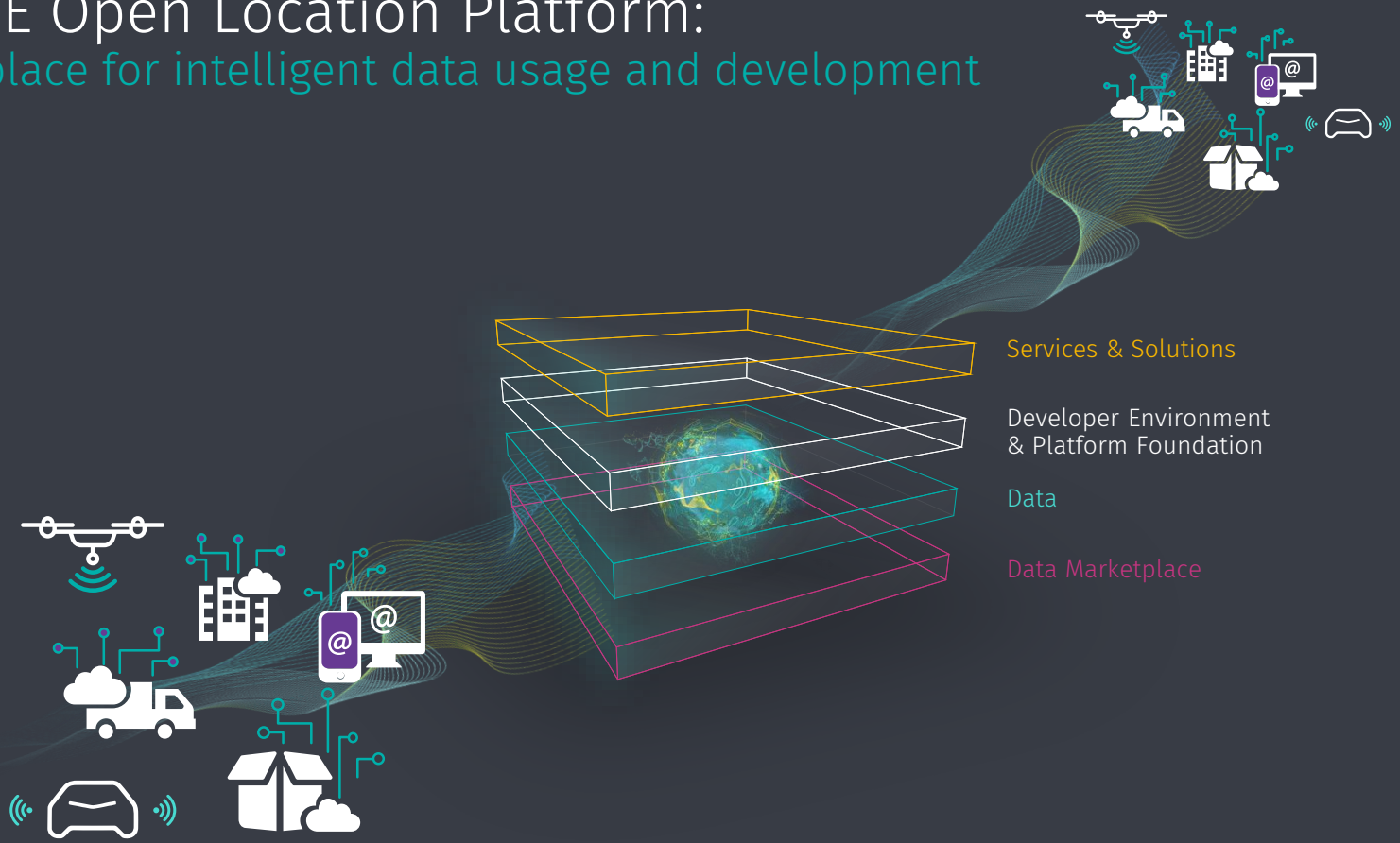
HERE Technologies ...

The Reality Index™:

Location & POIs
Vehicles
Beyond Roads
Things
People
Spatial & Aerial

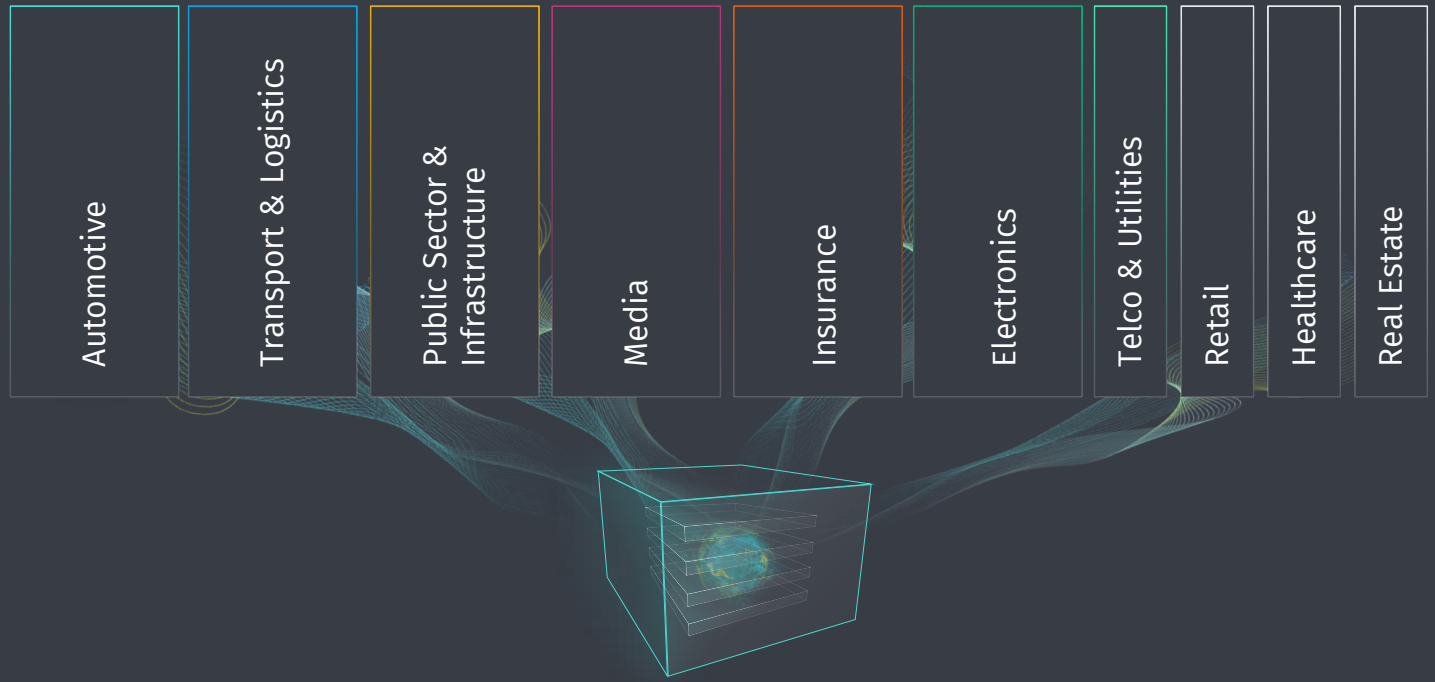
HERE Open Location Platform:

The place for intelligent data usage and development

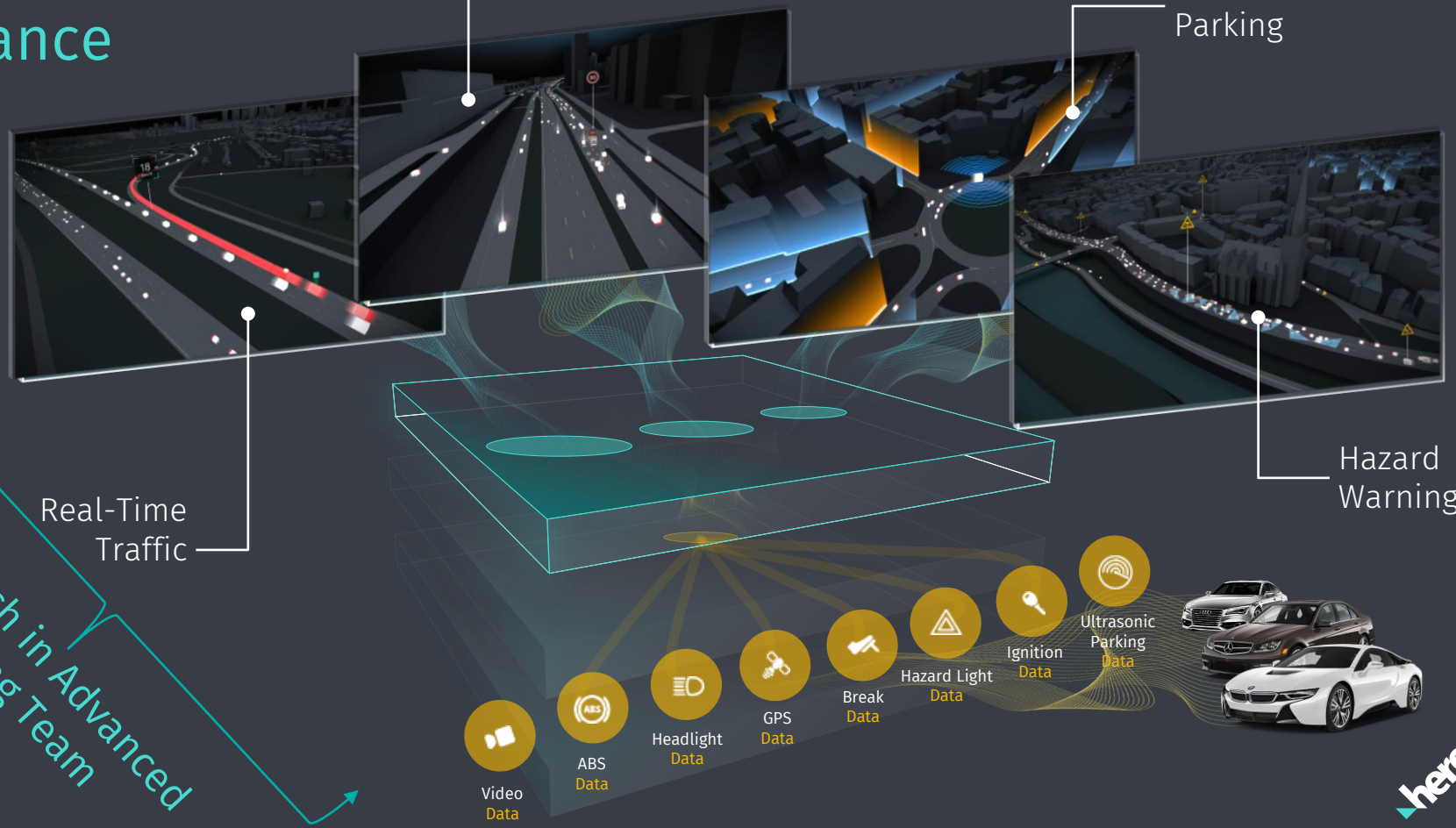


HERE Open Location Platform:

The “go-to” destination for location services in a variety of industries



Navigation & guidance



Video 1

Reality Index

https://www.youtube.com/watch?v=rqlJFBiNiww

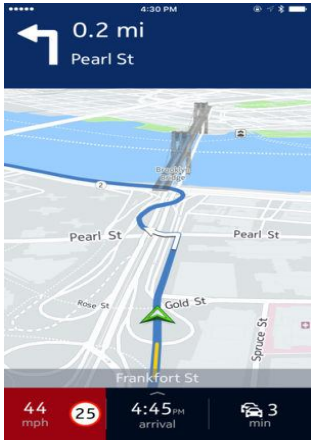
Rapid growth in the field of ITS …

Rapid Growth of Intelligent Transportation Systems

Taxi & Ride sharing

https://www.sharedmobility.news/wp-content/uploads/2017/10/shared11.png

Routing & Navigation



Logistics & Supply Chain

Connectivity (V2X)

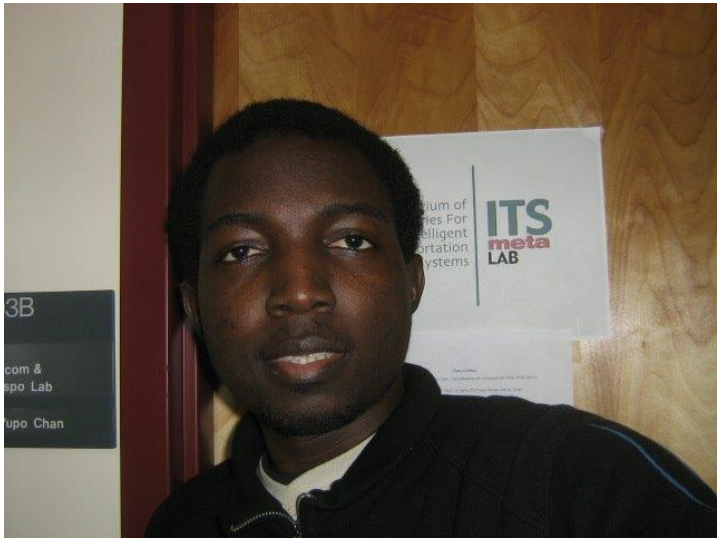
http://media2.govtech.com/images/940*636/connected+autonomous+vehicles1.jpg

Autonomous Driving

Smart Cities

Rapid Growth of Intelligent Transportation Systems

Data for Research …



Year 2007 at University of Arkansas at Little Rock

Graduate Research Assistant in ITS meta Lab
supervised by Dr. Yupo Chan
https://www.ualr.edu/yxchan/

- ITS has come a long way over the past decade …
- I was doing research on Advanced Traveler Information Systems, Road Traffic Monitoring & Inference, Routing with safety risk. [4][5]
- Exciting research field, but very little real-world data
- Today, there is a huge amount of data for ITS research; HERE's OLP and many state DOTs now have city open data, etc. [1][2][3][11]
- Graduate students of today are in the golden-era of ITS research
- Recent exponential increase in ITS related startups …
- Year 2019 for ITS, actually feels like year 1999 of the Web era

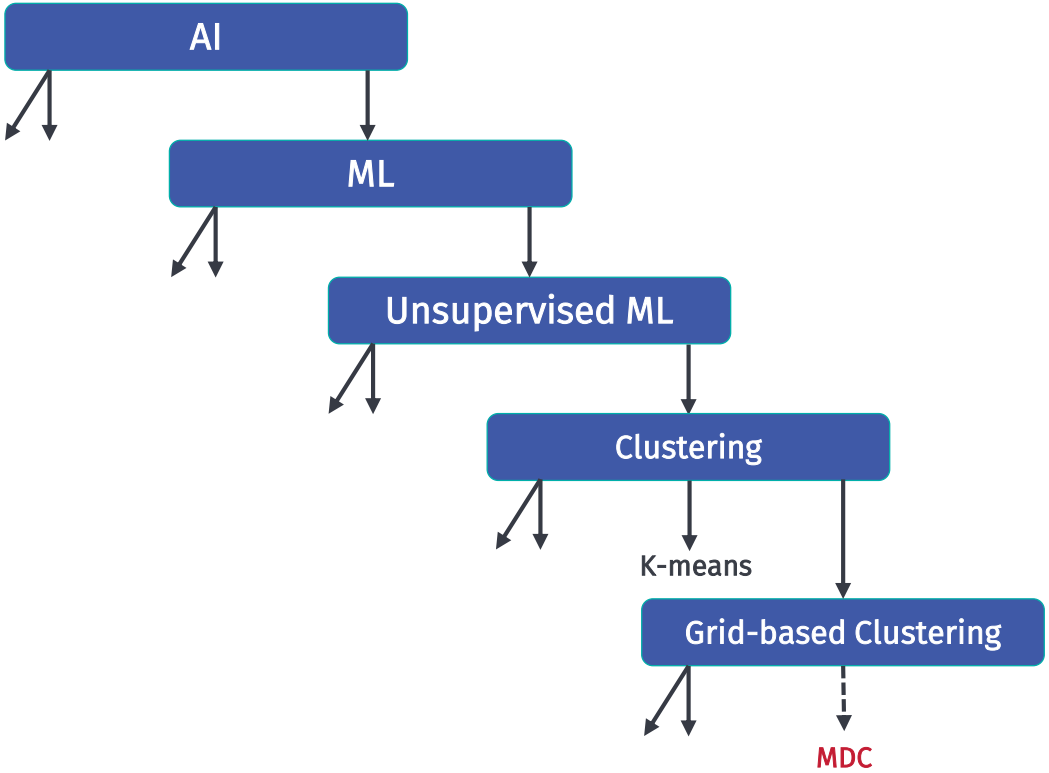
Tips for Applied Machine Learning/AI

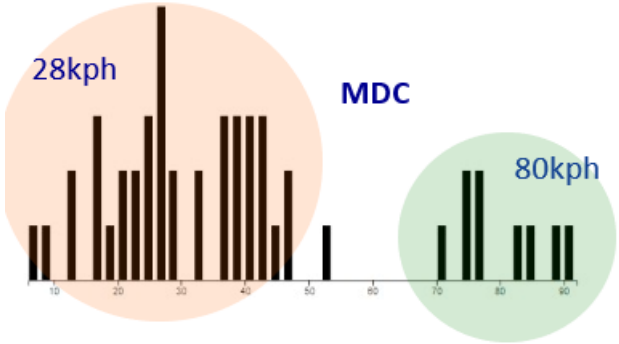
Data Science for ALL Engineering/Science Students …

- Data science is a big deal and the kind of data you work on can make a big difference
- The more familiar you are with the data the better you can do with the algorithms
- It is very ok to have area (data) of specialty
- Geospatial data is a golden data… Huge opportunity to apply ML & AI algorithms.
- Latest advancement in AI is exciting; *"what problem are you solving ?"* is the most important question
- Don't see AI & Machine learning as a separate field, see it as one of the most critical tools for your research work. Apply relevant algorithms to solve problems and by all mince do not pass a chance to improve a machine learning algorithm or invent new ones while solving problems in your field.

Example of Applied Machine Learning

HERE's Multimodality Detection and Clustering (MDC) Algorithm



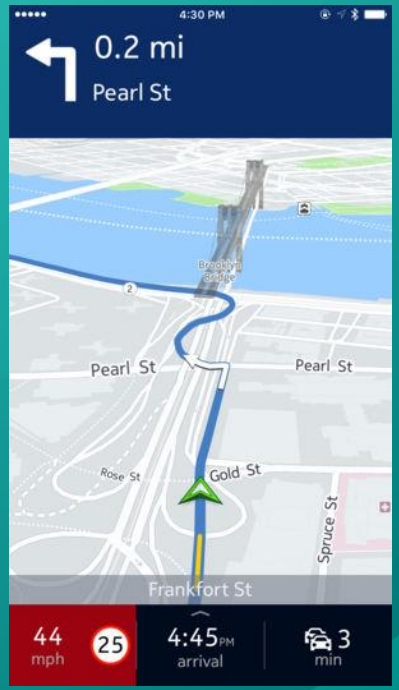


Tips for Applied Machine Learning/AI

- Focus on the problem rather than the tools
- Keep up with the trends in AI / ML and try to get intuitive understanding of new algorithms and latest technologies.
- As an applied scientist or engineer, you need to know what is possible, when to use it, tune it, improve it or invent a new method.
- The fact that the problem you are solving does not need a fancy ML algorithm, does not diminish the value and the impact of the problem. Find the most efficient solution to high impact problems
- Recent acceleration of research in AI/ML – too fast you cant keep-up, too critical you cant ignore.
- Apply science, but don't force science into Engineering [6]

"Everything should be made as simple as possible but not simpler" - Einstein

Navigation Systems ...

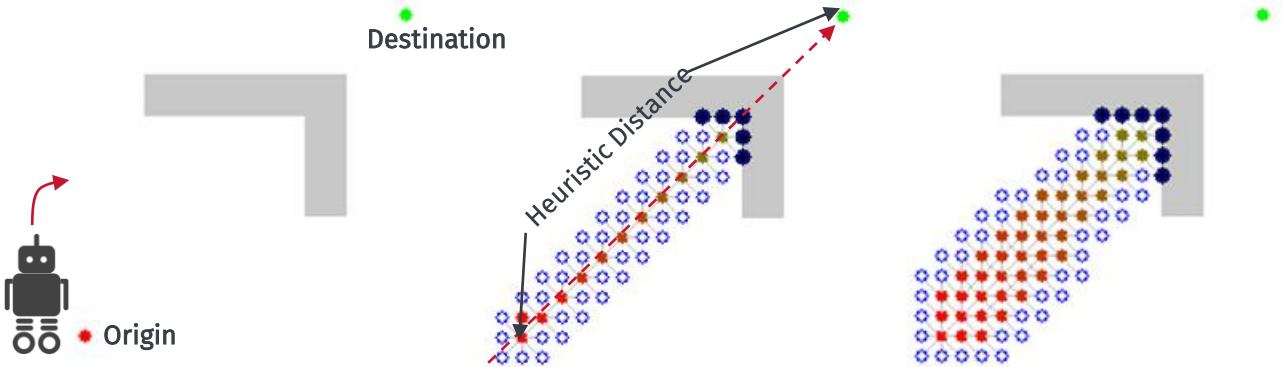


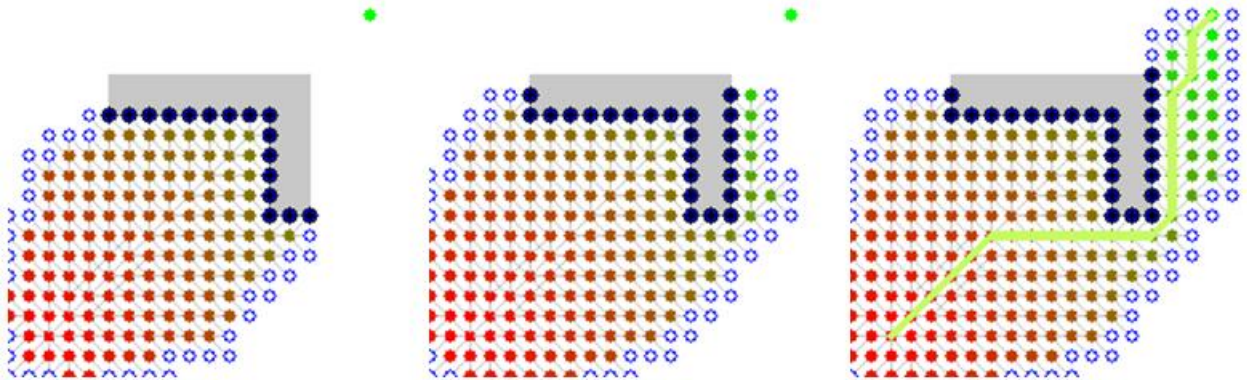
Basic Navigation System

Arc (edge) cost in a Transportation Network Graph

Find the fastest path to destination using A* Search

A* Search Algorithm ...

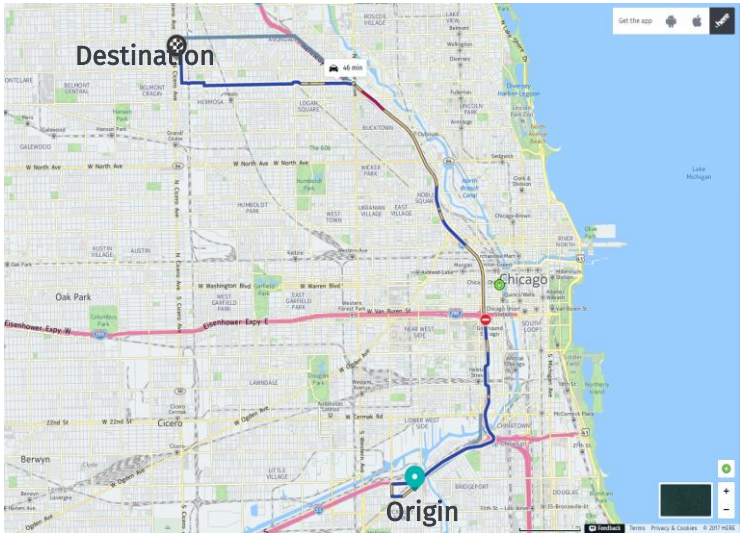


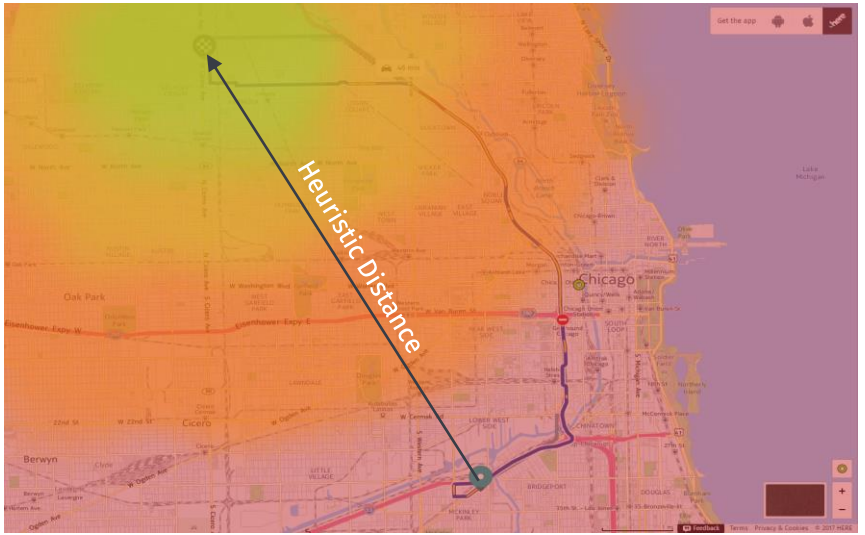


Nodes explored by A when goal node is behind an obstacle*

https://en.wikipedia.org/wiki/A*_search_algorithm

A* Search …





https://en.wikipedia.org/wiki/A*_search_algorithm

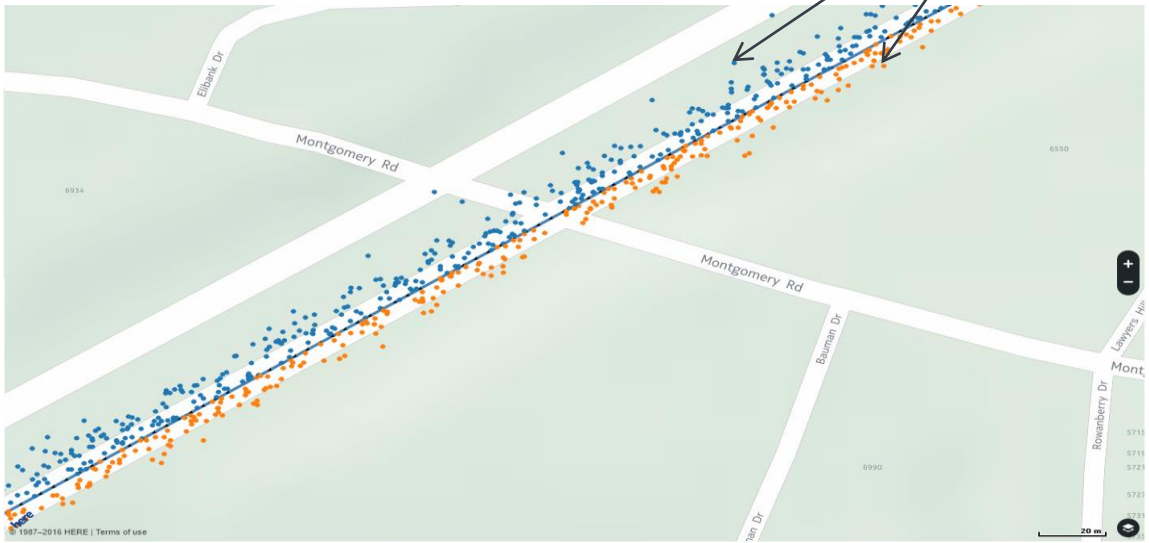
GPS Probe Data …

Typical Probe (GPS/GNSS) data

A GPS Probe

- Location (latitude & longitude)
- Instantaneous Speed
- Time
- Heading
- Anonymized-Device-ID

Noisy GPS probes



Potential of 5-20m error
Depending on device type,
Location and weather

Probe data types ...

Probe-points

(lat-lon, time, speed, heading)

Probe-Trajectory

(lat-lon, time, speed, heading, frequency, Anonymized_DeviceID)

Probe-path

(lat-lon, time, speed, heading, path_road_segments, Anonymized_DeviceID)

Origin-Destination(OD)

(O-time, D-time, O-lat-lon, D-lat-lon)

Huge opportunity for Data Science and geospatial modelling ...

Map-matching Overview

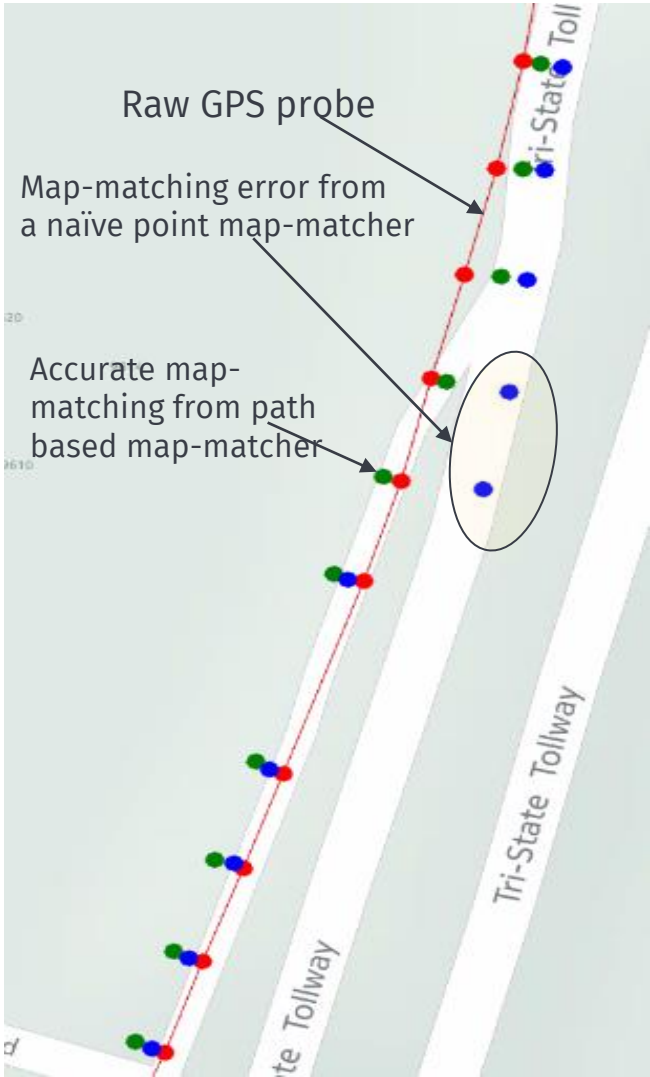
Fundamental algorithm for localizing noisy probes on the map

Point-Based Map-matching:

- Uses single probe-point for map-matching to the closest road-segment based on distance and heading.
- Very fast algorithm as it considers only a few links within x-meters radius around the probe.
- Easily fits into a real-time processing architecture for streaming probe data.

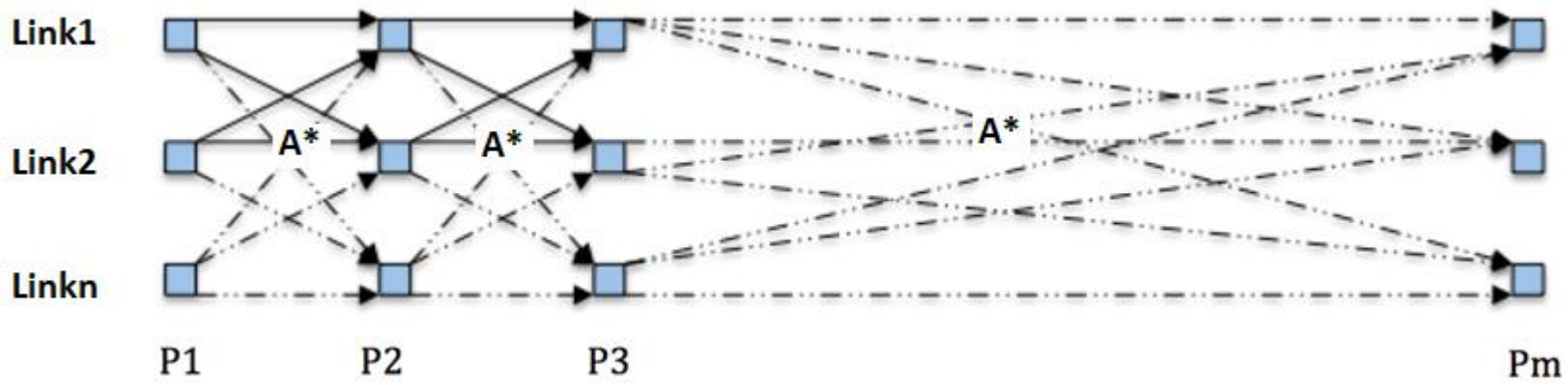
Path-Based Map-matching:

- Uses multiple probe-points to infer the most appropriate road segment
- Uses the point-based map-matcher to allocate probability scores to multiple links around a probe that are candidates for map-matching and many of them are based on Hidden Markov Model (HMM).



Path-based Map-matching

HMM with Viterbi inference



X — possible states ➔ possible links around the probe that the vehicle may be (Link1,Link2,…,Linkn)
y — possible observations ➔ probe points P1-> … ->Pm
a — state transition probabilities ➔ derived from shortest path distance as obtained from A* search
b — output/emission probabilities ➔ This is the probability of a vehicle being on Linkx

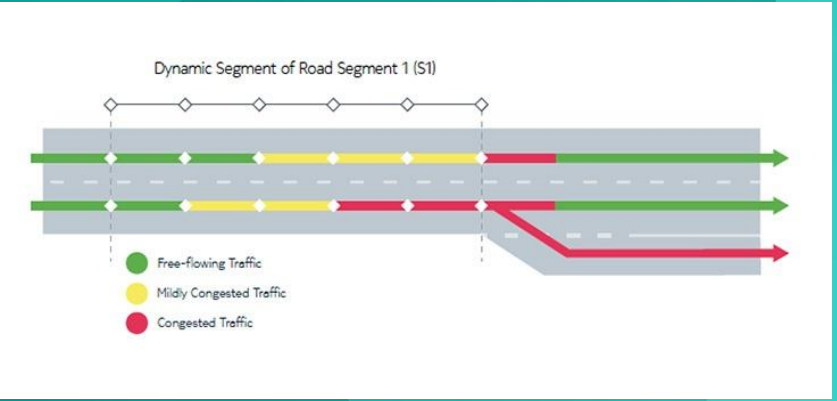
https://en.wikipedia.org/wiki/Viterbi_algorithm

A Nice Publication on MM => Hidden Markov Map Matching Through Noise and Sparseness, Paul Newson, John Krumm[10]

Improved Map-matching

Improved Map-matching

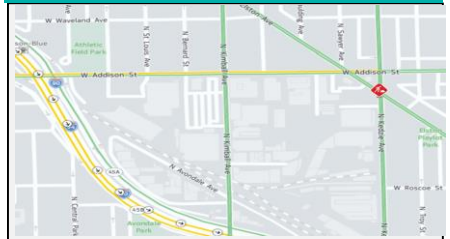
Lane-level Traffic



Lane Level Traffic is important for HAD

HERE Traffic was first to market with innovative features[9]

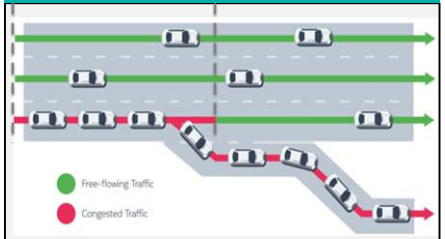
Reversible lane level



Report congestion on roads with changeable direction

Launched

Split Lane Level Traffic



Lane level precision at highway splits/branches

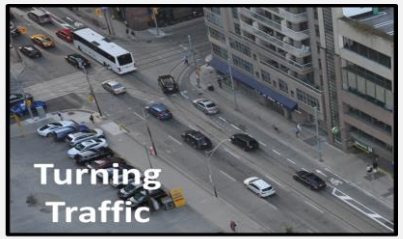
Launched

HOV Lanes

Report traffic separately for HOV only lanes

Planned

Arterial Turn Lanes



Turn lane travel time differences at intersections

Planned

HERE to power live traffic data for Audi in North America and Europe

https://www.here.com/en/company/newsroom/press-releases/2019-08-01-0

Video 2 - HERE Traffic Products

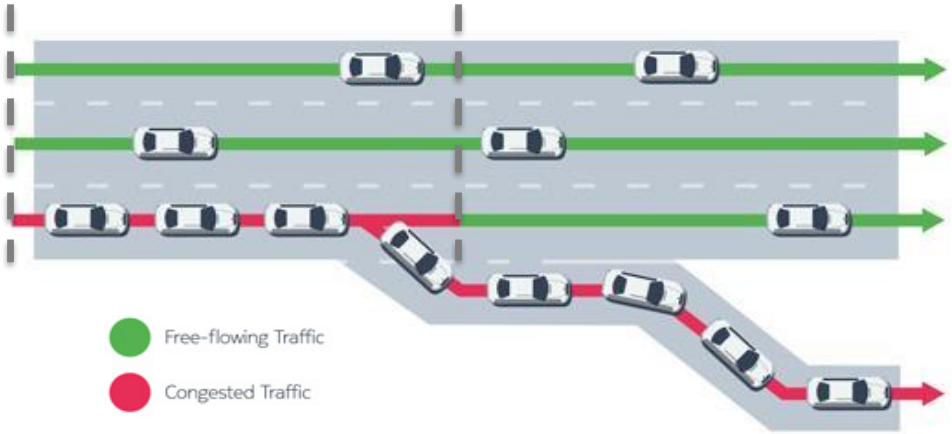
Overview of HERE Traffic Products

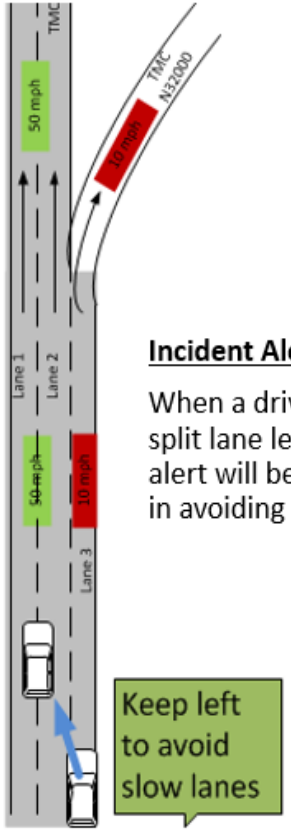
https://www.youtube.com/watch?v=24tgONHEbSM

Split Lane Traffic (SLT)

HERE unveils first lane-level traffic reports[8][9]

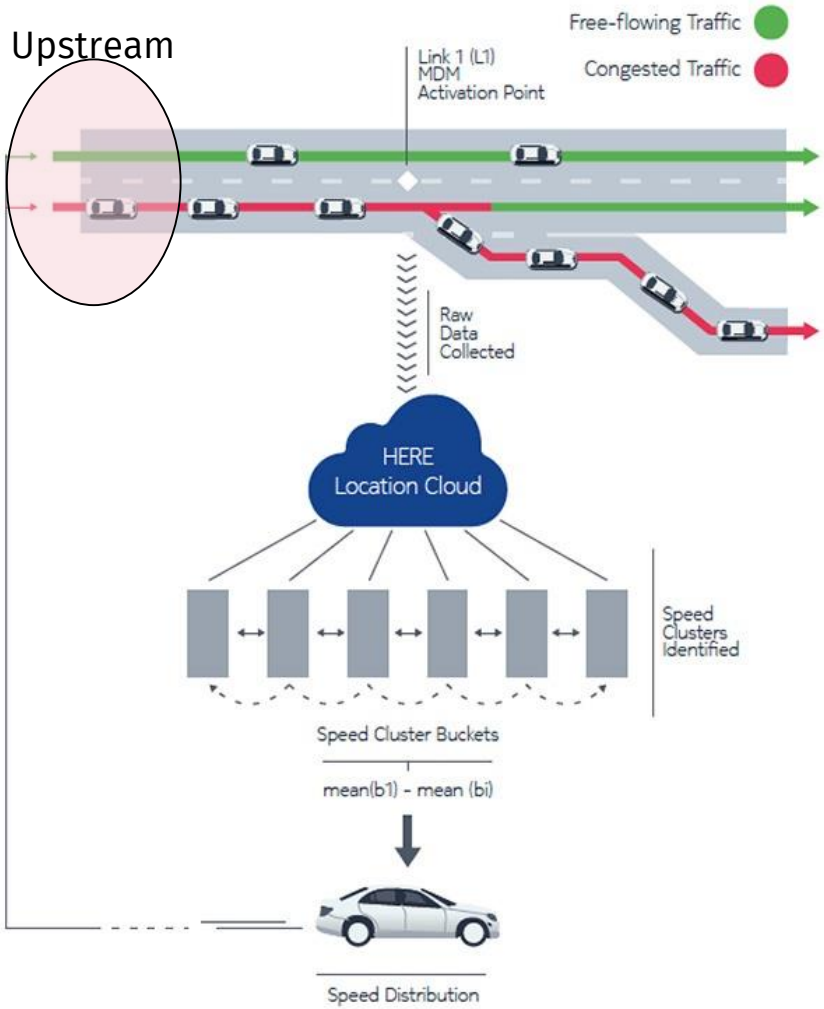
SLT detects bimodal speed conditions leading to a branch on highways, such as highway splits or ramps.
There may not be congestion in all lanes, but there can be rapid lane level slowdown based on branching traffic conditions.
Use case: Improved Routing/ETA and Safety.





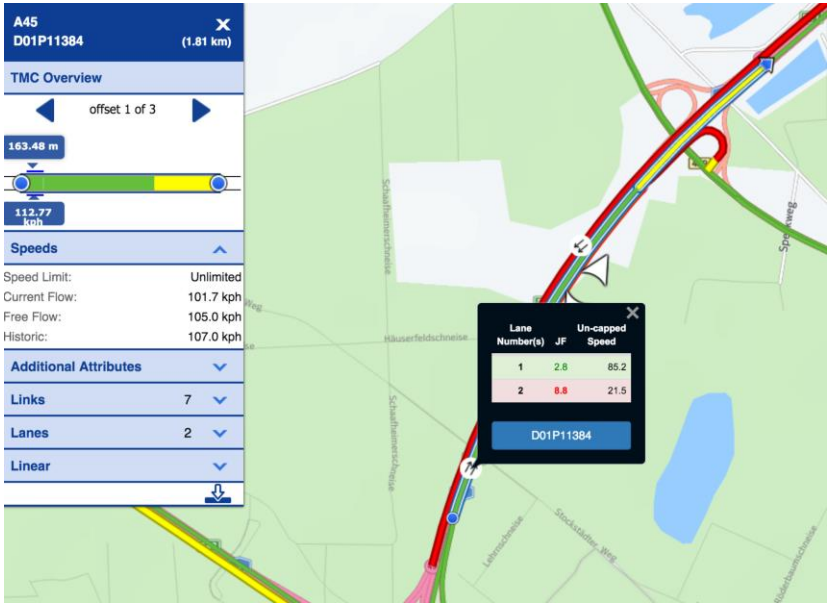
Incident Alert Use Case

When a driver is on a road with split lane level traffic ahead, an alert will be provided to assist user in avoiding the congested lane(s).

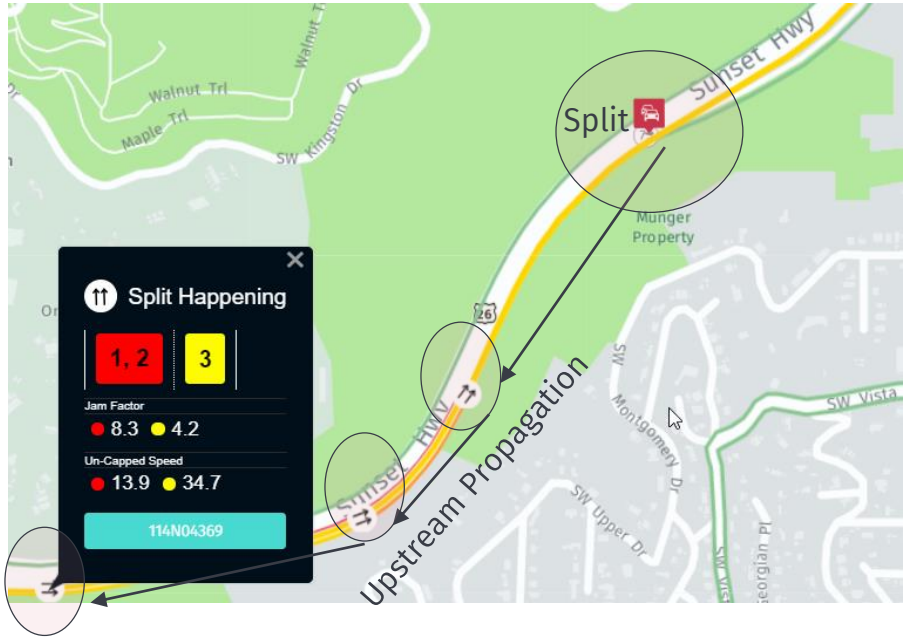


- A Variant of the grid-based clustering algorithm (MDC) is used to automatically detect an SLT event and produce speed clusters
- The algorithm also detects how far upstream the SLT event propagates

Example of SLT Events



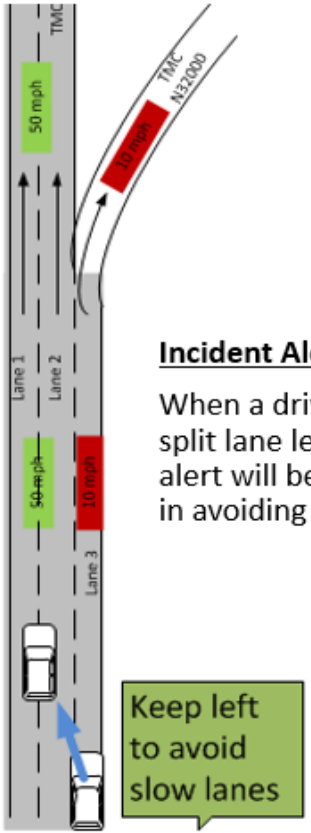
SLT on an Highway in Portland



Video 3 – SLT's Safety Use-case

Found a random YouTube Video showing the importance of lane-level safety warnings for navigation systems:

https://www.youtube.com/watch?v=U2yHjyavL0Y&feature=youtu.be



Incident Alert Use Case

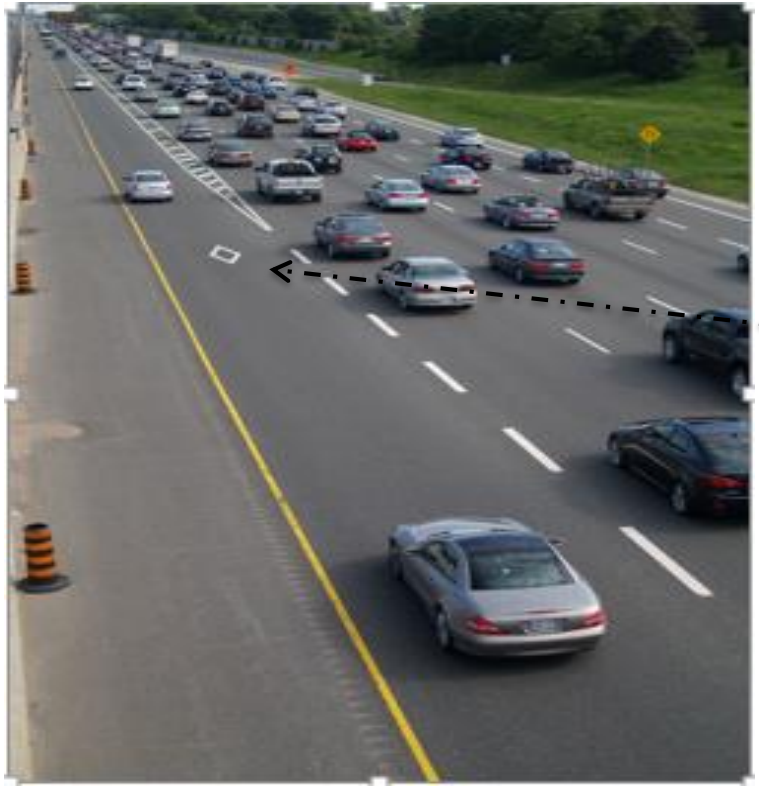
When a driver is on a road with split lane level traffic ahead, an alert will be provided to assist user in avoiding the congested lane(s).

Lane-level Granularity Is Key to Autonomous Driving[12]

Some Research Challenges ahead ...

Can we go beyond SLT ?

HOV Lane Traffic, Automatic Detection of HOV Events, etc.



HOV Traffic is a more challenging problem.

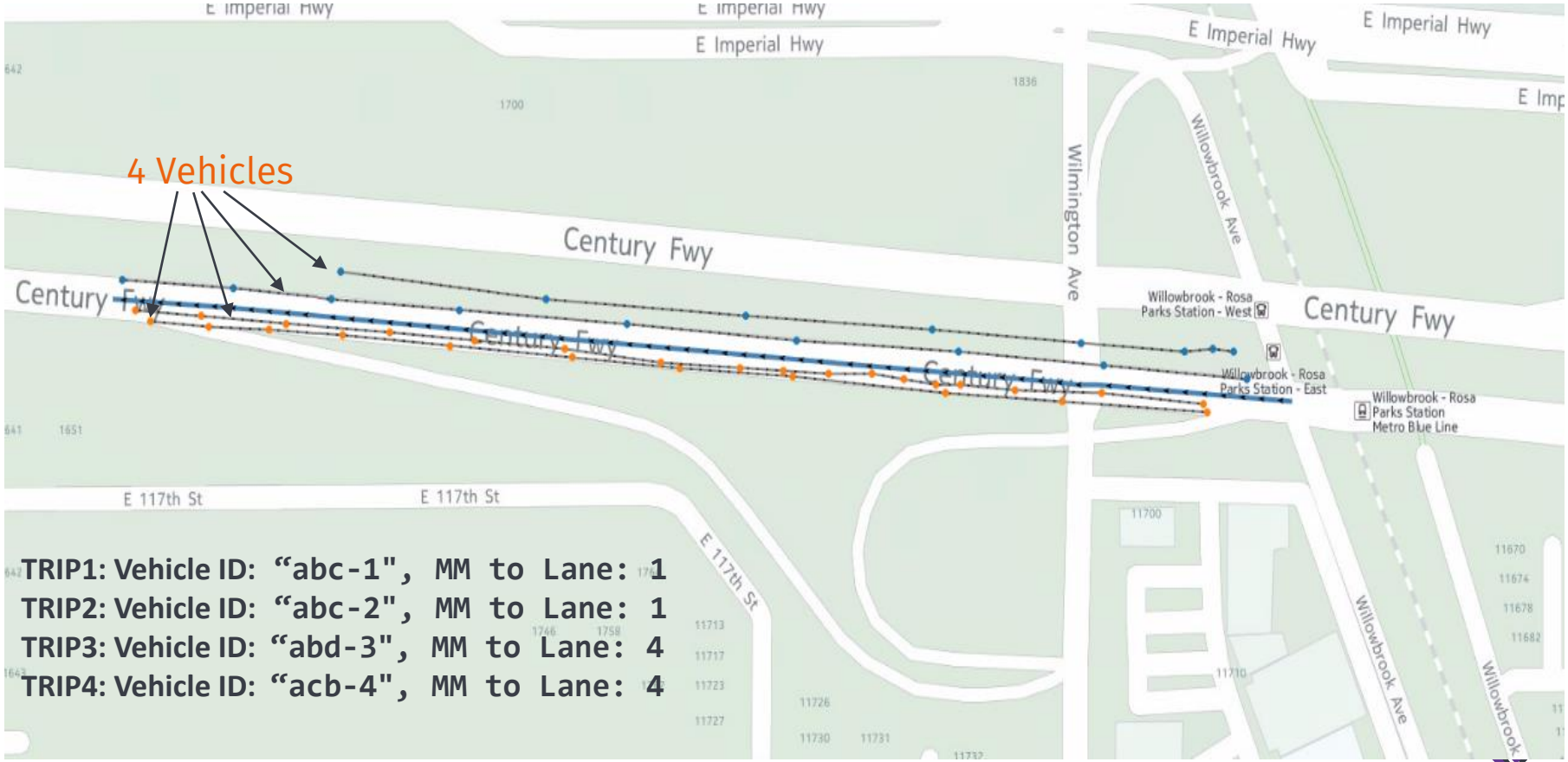
SLT does have road splits downstream, but HOV does not.

[34] https://en.wikipedia.org/wiki/High-occupancy_vehicle_lane

Is lane-level map-matching of noisy GPS probes ever a possibility ?

Please Note:
Lane 1 is the right-most lane
Lane 5 is the left-most lane

Example of Lane-level Map-matching

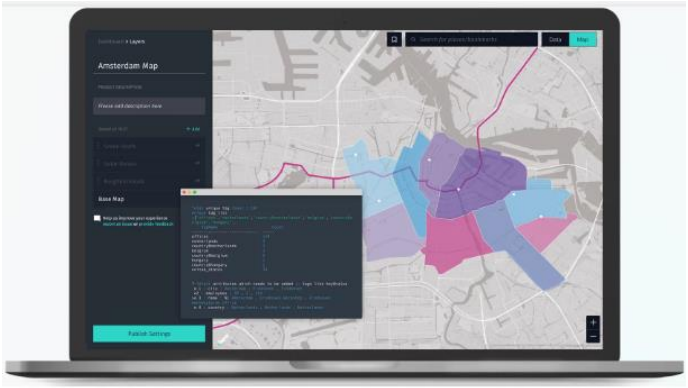


Opportunities …

Many opportunities

Join us in the journey to design and shape the autonomous future

Developer Tools ➔ HERE XYZ[13]



XYZ

Top Feature Enhancements Driven by HERE XYZ Beta Participants

https://developer.here.com/blog/top-feature-enhancements-here-xyz-beta?cid=Developer-LinkedIn-CM-0-devblog-0&utm_source=LinkedIn&utm_medium=social&utm_campaign=CommsShare_2019Q1

New Video Tutorial: https://www.youtube.com/watch?v=E78Pw2d-kpM

Jobs ➔

https://www.here.com/en/careers/jobs#/

Rich location data [11]

Car sensor data

OLP | SENSOR DATA | REAL-TIME

Live road conditions

OLP | TRAFFIC | ACCIDENTS | REAL-TIME

Road construction

OLP | TRAFFIC | CONSTRUCTION

Thank you

Contact
Here.com

References

[1] New York City Taxi Data (2010-2013), Brian Donovan and Dan Work, December, 2014

https://meduse-main.s3.us-east-2.amazonaws.com/983/2188/DOI-10-13012-j8gn93h8/dataset_files/New_York_City_Taxi_Data_2010-2013.pdf?response-content-disposition=inline%3B%20filename%2D%22New_York_City_Taxi_Data_2010-2013.pdf%22%3B%20filename%2A%3Dutf-8%22New_York_City_Taxi_Data_2010-2013.pdf%22&response-content-type=application%2Fpdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIVPSOGWCJITGMKEQ%2F20190401%2Fus-east-2%2Fs3%2Faws4_request&X-Amz-Date=20190401T201148Z&X-Amz-Expires=604800&X-Amz-SignedHeaders=host&X-Amz-Signature=eda1920f3faa84ee9bdb8e4536bc118000cdefe064976326a3bd8a53e01289d7c

[2] New York TLC Trip Record Data: https://opendata.cityofnewyork.us/ https://www1.nyc.gov/site/tlc/about/tlc-trip-record-data.page

[3] Chicago Data Portal: https://data.cityofchicago.org/browse?category=Transportation

[4] A microstate spatial-inference model for network-traffic estimation, Adeyemi J.Fowe, Yupo Chan

https://www.sciencedirect.com/science/article/pii/S0968090X13001757

[5] Policy-Based Routing in Stochastic Networks with Incident Risks: A Deviation from First-in-First-out Property, Fowe Adeyemi James, Chan, Yupo

https://trid.trb.org/view/1092621

[6] Artificial Intelligence – The Revolution Hasn't Happened Yet, Michael Jordan,
https://medium.com/@mijordan3/artificial-intelligence-the-revolution-hasnt-happened-yet-5e1d5812e1e7

[7] Latest from HERE Technologies (Linkedin):

https://www.linkedin.com/company/here/

[8] Solution to key traffic problem required a fresh look at existing data

https://www.linkedin.com/pulse/solution-key-traffic-problem-required-fresh-look-existing-tony-belkin/

[9] HERE unveils first lane-level traffic reports

https://360.here.com/2015/11/09/here-unveils-first-lane-level-traffic-reports/

[10] Hidden Markov Map Matching Through Noise and Sparseness, Paul Newson, John Krumm

https://infolab.usc.edu/csci587/Fall2016/papers/Hidden%20Markov%20Map%20Matching%20Through%20Noise%20and%20Sparseness.pdf
https://www.microsoft.com/en-us/research/publication/hidden-markov-map-matching-noise-sparseness/

[11] HERE's OLP Data: https://developer.here.com/products/open-location-platform

[12] HERE's Electronic Horizon: https://www.youtube.com/watch?v=HCIHPeiWoLw

[13] HERE XYZ for Developers https://explore.xyz.here.com/