### Revolutionizing Road Transportation with Artificial Intelligence Empowered Technologies

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for

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### **Road Transportation Is Important**

Financial

art-manufacture addressed

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#### Unexpected drop in August retail sales as supply chain problems weigh on stores

2016= 2128 余日

> 4703 上海道新闻社

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# Vetocknik Why traffic nightmare Netocknik S now normal in No. It's crawl but true, we Vetocknik No. It's crawl but true, we Veto

some way to go to mutch Cologue,

VILLIONS of frustrated drivers have unpected it and now it's conour roads really are the most sugested in Europe

on British towns feat the 50 most gridlocked cities tross the continent, with eight in the new research reveals. random has the worst traffic in ritain with about 35 per cent of the units regularly clogged up However, it is only third overall, sels and Warsaw, in the an propiled by saturar con and table

Tom Tom Edisburgh and Manchester also fo view, with Bradford, Bel mant in the tot and Birmingham taking at. Oxford positions just outside out of the first of main roads en congestion is based plated from Tomingention is defined s a journey that should be one hour 20 minutes longer be ause of traffic flow. London's traffic flow has decreased



sels, said TomTom. But London has have made good progress in curting

replarity comprised. Some cities a spekroman for ToniTon, Ober coies featured in the top 50 are found in Spain, Holland and Norway

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Source: Google images

Driving home

Javed calls code of



### **Road Transportation Challenges**

What are the top five challenges in road transportation in the US?

- In the United States, road transportation faces several specific challenges that can often be region-specific due to the vast size and diverse geography of the country. Nonetheless, some of the top challenges that are generally acknowledged across the U.S. include:
- 1. Aging Infrastructure: The U.S. has a large network of roads and highways that have been underfunded for years. Many bridges, tunnels, and roadways are in need of repair or replacement. The American Society of Civil Engineers often gives poor grades to the nation's infrastructure in its report cards.
- 2. **Congestion**: Congestion in U.S. cities and on major highways leads to significant time delays, increased fuel consumption, and higher emissions. Traffic congestion is especially severe in large metropolitan areas and on major arteries across the country.
- 3. Safety and Traffic Fatalities: Road safety continues to be a significant concern in the U.S. Despite advances in vehicle safety, traffic fatalities and serious injuries are a leading cause of death, especially among young people. The challenges include addressing distracted driving, driving under the influence, and the safety of vulnerable road users such as pedestrians and cyclists.
- 4. Environmental Concerns: The U.S. transportation sector is one of the largest contributors to national greenhouse gas emissions. There is a growing challenge to reduce the carbon footprint of road transport by encouraging the use of more fuel-efficient vehicles, developing electric vehicle infrastructure, and promoting alternative transportation options.
- 5. Equity and Accessibility: There's an increasing recognition of the need for equitable transportation that serves diverse populations including low-income neighborhoods, people with disabilities, and those living in rural areas. Access to reliable and affordable transportation is crucial for access to jobs, education, and healthcare.

- Aging Infrastructure
- Congestion
- Safety and Traffic Fatalities
- Environmental Concerns
- Equity and Accessibility
- Labor Shortage



### **Road Transportation Challenges**





Picture source: https://www.transportation.gov/mission/us-dot-strategic-plan-fy-2022-2026



#### Autonomous Vehicles



Image Source: <a href="https://www.autoweek.com/news/green-cars/a41351858/torc-robotics-autonomous-trucks/">https://www.autoweek.com/news/green-cars/a41351858/torc-robotics-autonomous-trucks/</a>



#### Connected Vehicles



Image Source: https://www.volpe.dot.gov/sites/volpe.dot.gov/files



#### Electric Vehicles



Image Source: http://nhcleancities.org/wp-content/uploads/2016/08/electric-vehicles-powerered-by-solar.jpg



#### Smart Infrastructure





**Crowdsourcing Data and Applications** 



Image Source: https://scdn.androidcommunity.com/wp-content/uploads/2012/01/waze-3.jpg



#### Bigdata Analytics





#### Ride Resource Sharing



Image Source: http://www.theyeshivaworld.com/wp-content/uploads/2016/06/14.jpeg



#### Mobility as a Service (MaaS)



Image Source: http://www.theyeshivaworld.com/wp-content/uploads/2016/06/14.jpeg



### Al Is a Critical Binding Agent





#### **Power of These Disruptive Technologies**





### **Proof of the Effectiveness**



Image Source: https://arekskuza.com/the-innovation-blog/uber-business-model/

# **AI Applications in Transportation**

Transportation is likely to be one of the first domains in which the general public will be asked to trust the reliability and safety of an AI system for a critical task.

- One Hundred Year Study on Artificial Intelligence (AI100), Stanford University,





ACTRAN

REGION 10



## Al & Transportation

AI can improve performance beyond that provided by other analytics techniques. The top five potential incremental value from AI:

- 1. Travel
- 2. Transport & Logistics
- 3. Retail
- 4. Automotive and assemble
- 5. High tech

Breakdown of use cases by applicable techniques, %

Full value car be captured using non-Al techniques Al necessary to capture value ("greenfield") AI can improve performance over that provided by other analytics techniques

Potential incremental value from AI over other analytics techniques, %

% Travel	128 89
	89
I ransport and logistics	
Retail	87
15 Automotive and assembly	85
High tech	85
Dil and gas	79
Chemicals	67
Media and entertainment	57
Basic materials	6
G Agriculture 5	5
Consumer packaged goods 5	5
Banking 50	
Healthcare systems and services 44	
69 Sectors 44	
Telecommunications 44	
Pharmaceuticals and medical products 39	
Insurance 38	
Advanced electronics/semiconductors 36	
Aerospace and defense 30	

https://www.mckinsey.com/featured-insights/artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-the-age-of-artificial-intelligence/the-promise-and-challenge-of-the-age-of-artificial-intelligence/the-age-of-the-age-of-the-age-of-artificial-intelligence/the-age-of-



### Al Is Hot in Transportation Research

Published papers on AI research and applications in transportation Data source: Google Scholar

#### Paper Publication related with AI & Transportation





### Hot Topics in Al for Transportation

#### Natural Language Processing



#### **Reinforcement Learning**



#### Computer Vision & Edge AI







**Block Chain** 







### **NLP Method for Truck Parking Prediction**

 Cost-effective solution for truck parking using NLP techniques

> Sensor-fused detection Customized Machine Learning

Date 6/3/2021			То	Total slots:		
Time 9:41:05 PM			Available Now: 5			
Realtime Scatter Cree	k safety rest are	ea parking	g predic	tion (renew every 5	minutes	
10 Minutes later	very likely	have	3-6	slots availabile		
30 Minutes later	very likely	have	3-6	slots availabile		
1 hour later	very likely	have	3-6	slots availabile		
2 hour later	very likely	have	3-6	slots availabile		
3 hours later	very likely	have	3-6	slots availabile		
4 hours later	very likely	have	0-2	slots availabile		
very likely like > 90% confidence rate 30%	ely 5-90% contidence rate	probably Strs-ap	y Si confiden	possibly carate <30% confidence	rate	

Yang, et al. 2022: https://ieeexplore.ieee.org/abstract/document/9582619





### **Ride Sharing Recommendation**







# **Reinforcement Learning (RL)**







# **RL for Autonomous Driving**

- Motivations
  - Autonomous driving consists of multiple tasks. For example, higher-level tasks pertain to decision-making based on reasoning of the surrounding environment.
  - Long-term decisions are hard to model in traditional models
  - Uncertainties are interrelated in autonomous driving scenarios.
- Applications
  - Lane changing
  - Car following



Zhu et al., 2020: <u>https://doi.org/10.1016/j.trc.2020.102662</u>



# **GNN for Traffic Forecasting**

#### Motivations

- Measurements of traffic variables on transportation networks are becoming increasingly common.
- Two data points might be spatially close in Euclidean space but interact independently. The true distance is roadway driving distance.
- The need to predict traffic characteristics in a short or long future time horizon for different ITS applications is strong.
- Solutions
  - GNN + recurrent NN variants (vanilla RNN, LSTM, sequence to sequence)



Cui et al., 2020: https://doi.org/10.1016/j.trc.2020.102674



# **Block Chain for Transportation**

- Supply chain
- Lack of information for consumer about the origin of food products
- Electric vehicle charging
  - Allow customers to query charging stations for the lowest available price
- Smart vehicle
  - Malicious attacks can compromise passengers' safety





Singh, et al., 2020: <u>https://www.sciencedirect.com/science/article/abs/pii/S0167739X19316474</u>



# **Blockchain + Al for Transportation**

A Blockchain-enabled Intelligent IoT Architecture with Artificial Intelligence

- Edge intelligence:
  - Al uses analytic tools for reliable data mining (feature extraction, scaling, and representation) of big unstructured data from IoT devices.
  - Blockchain technology provided peer to peer connection to unstructured IoT devices in networks for security and privacy.
- Fog intelligence:
  - Al technologies are deployed to train machine learning models and make decisions as rapidly as possible at fog intelligence.
  - Blockchain technology provides a distributed repository in which every device has its copy of the whole ledger.
- Cloud intelligence:
  - Intelligent agents of AI are used in cloud intelligence to collect, select, analyze the data from ambient environments using centralized methods.
  - Blockchain provides the distributed pattern for secure big data analysis in IoT.

Singh et al., 2020: https://www.sciencedirect.com/science/article/abs/pii/S0167739X19316474





Al empowered Sensing Tech 28



Sample Applications
 Various Speed Limit
 Volume by 13 Classes
 Adaptive Control
 Hazard Warning
 Traffic Environment Sensing







# **Edge Computing**

#### **Edge Computing**

- Computational processing of sensor data away from the centralized nodes and close to the logical edge of the network (where the data is generated)
- Empowered by AI technologies, data can be processed by an IoT device itself or by a local computer, rather than being transmitted to a cloud data center.







Raspberry Pi Jetson Nano Jetson Xavier NX





### Mobile Unit for Sensing Traffic (MUST)

#### **Mobile Unit for Sensing Traffic**

- Operation Temperature
- Operation Relative Humidity
- Ingress Protection
- Power Supply
- Energy Consumption
- CPU
- Communication
- Operation System
- Local Data Storage
- Weight
- Dimensions

10% ~ 90% IP 65 12V(DC) < 35Watts ARM1176JZF-S 700 MHz 3G/4G/5G, Ethernet Linux Micro Secure Digital (SD) Card 10 pounds 170 mm (length), 170 mm (width), 300 mm (height)





-40 °C ~ 70 °C





32

#### **Object Detection and Classification**





- Traffic volume detection and vehicle classification
  - Transfer learning
  - MobileNet pretrained on ImageNet and finetuned on MIO-TCD



	Car	Truck	Bus	Cyclist	Background
Car	91%	5%	2%	2%	0
Truck	6%	87%	4%	3%	0
Bus	1%	2%	96%	1%	0
Cyclist	2%	2%	1%	95%	0
Background	0	0	0	0	100%



#### **Road Surface Conditions Monitoring**





	Dry	Snowy	Icy	Wet
Dry	97.5%	0.4%	0.7%	1.4%
Snowy	0.2%	97.9%	1.8%	0.1%
Icy	1.6%	1.6%	93.6%	3.2%
Wet	0.6%	1.7%	2.4%	95.3%





## **Edge-Al for Environment Sensing**

#### **Camera View Dehaze for Visibility Detection**



**Original Image** 

Scattering Map

De-hazed Image



# **Edge-Al for Environment Sensing**

#### **Visibility Detection**

Threshold Visibility	± <b>5</b> %	±10%	<b>±20</b> %
V <sub>s</sub> < 500 m	85.29%	89.14%	93.18%
$500m \le V_s < 1000 m$	88.17%	90.25%	95.42%
$1000m \le V_s < 2000 m$	90.36%	93.22%	97.03%
$V_s \ge 2000 \text{ m}$	91.23%	95.78%	98.75%
Overall	89.27%	92.15%	96.61%





# Edge AI for Highway Monitoring

# **Mobile App** for device management, real-time data collection, event detection & warning.

1	1	STIC Can	nera 1	LIVE Status	LIVE Status
Device List	Click on locations to view LIVE STATUS	and the second		STIC Bellevue 1	STIC Bellevue 1
Device ID Device Name					ALERT Alert Type: Long queue
Latitude				STIC Bellevue 2	47.562525, -122.099531
Longitude Status	Bad	Date: Time: Location: Sensor ID: Traffic flow (vehicles per hour): Truck percentage (%):	2021-10-04 10:24:54 Lakemont Bivd, Bellevue STIC Bellevue 1 570 1.5		Bellevue Time:
Address	or	Temperature (°C): Humidity (%):	15 86	STIC Bellevue 3	10/20/2021 11:08 am PDT
Add New Device skip	SEE ALL				
III O <	III O <		<	III O	< 111 O <



### **Pilot Application in Yakama Nation**



This pilot project received the FHWA 2023 Build a Better Mousetrap Innovative Project Award!



# Highway Safety Improvement

Technologies are available to help prevent crashes and reduce the severity of such tragedies!

Image source: https://www.thedrive.com/news/44961/50-car-pileup-in-pennsylvania-kills-at-least-five-in-whiteout-conditions



# **AI Applications in Transportation**

#### Successful AI applications needs domain knowledge



Image source: https://www.researchgate.net/figure/Transportation-network-with-nodes-and-network-links\_fig4\_346440166



# **Edge Computing for ATUs**

At some point in the day, everyone is a pedestrian. Walking accounts for about 11% of all trips. Unfortunately, pedestrian injuries and fatalities remain high. In 2021, 7,388 pedestrians were killed – a 13% increase from 2020 – and more than 60,000 pedestrians were injured nationwide (source: NHTSA).







# **Edge-Al for VRU Data Collection**

#### **Pedestrian Detection + Tracking**





# **Edge-Al for VRU Data Collection**

#### **Diverse Pedestrian Groups Sensing**



YOLO V4 Object Detection Model

**Our Pedestrian Sensing Method** (**Object Detection + Density Detection**)



# **Edge Computing for ATUs**

#### System Design:

- Encoder-decoder (ED)
- Density Map Segmentation & Clustering (DMSC)
- Local Patch Refinement (LPR)





# **People's Opinions Are Different**



Image source: https://cdn.cnn.com/cnnnext/dam/assets/220505130714-elon-musk-bill-gates-super-169.jpg



# Government Has a Role to Play



President Joe Biden issued an executive order on AI that many experts say is a significant step forward on Nov. 2, 2023

- Civil Rights
- Data Usage and Privacy
- Regulation on AI-Generated
  Products
- Etc.



### Huge Potential for AI & Transportation

#### AI JOB POSTINGS (% of ALL JOB POSTINGS) in the UNITED STATES by SECTOR, 2021

Source: Emsi Burning Glass, 2021 | Chart: 2022 Al Index Report



https://aiindex.stanford.edu/wp-content/uploads/2022/03/2022-AI-Index-Report\_Master.pdf



### Huge Potential for AI & Transportation

#### TOP CONTRACT SPENDING on AI by U.S. GOVERNMENT DEPARTMENT and AGENCY, 2000-21 (SUM)

Source: Bloomberg Government, 2021 | Chart: 2022 Al Index Report



Contract Spending (in billions of U.S. Dollars)

https://aiindex.stanford.edu/wp-content/uploads/2022/03/2022-AI-Index-Report\_Master.pdf



### Huge Potential for AI & Transportation

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Source: Bloomberg Government, 2021 | Chart: 2022 Al Index Report



https://aiindex.stanford.edu/wp-content/uploads/2022/03/2022-AI-Index-Report\_Master.pdf



#### **Thanks for Your Attention!**

Let us work together for a safer, greener, more efficient, and more equitable future transportation system!



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