NCDOT Center of Excellence on Mobility and Congestion

Project 1
Deep Learning Software for Traffic State Prediction

March 18, 2021 Year 1 meeting
Project Team

• Principal Investigator – **Sambit Bhattacharya, Ph.D.**
  – Professor of Computer Science – Fayetteville State, Dept of Math & Computer Science
  – Director – Intelligent Systems Lab (ISL)

• Co-Principal Investigators
  – **Ali Hajbabaie, Ph.D.** – NC State, Assistant Professor in the Department of Civil, Construction, and Environmental Engineering
  – **Noel Greis, Ph.D.** – NC State, Research Full Professor, Poole College of Management
  – **Hyoshin (John) Park, Ph.D.** – NC A&T, Assistant Professor in the Department of Computational Science & Engineering

• Senior Researchers
  – **Murat Adivar, Ph.D.** – Fayetteville State, Associate Professor, Broadwell College of Business & Economics
  – **George List, Ph.D.** – NC State, Professor in the Department of Civil, Construction, and Environmental Engineering
  – **Thomas Chase, Ph.D.** - NC State, Research Associate in the Institute for Transportation Research and Education
Project Goals

• Develop edge computing and deep learning software to improve estimation of traffic state parameters on arterials by fusing video, loop detector and Bluetooth sensor data

• Test software with traditional signal control and a CV-enabled signal control algorithm in VISSIM

• These capabilities will assist in
  – improved performance measures for integration into existing tools like ATSPM
  – temporary deployment for signal retiming or loop detector calibration
  – driver information through connected vehicle applications
Methodology

- Deep/machine learning AI approach to prototype software design
- Steps include –
  - Data collection on real and simulated traffic
  - Develop single stream video analytics
  - Develop multi stream video analytics
  - Develop data fusion methods
  - Test hypothesis that advanced traffic signal control algorithm performs better optimization with this traffic state estimate
# Project Schedule and Progress to Date – Task 1 to Task 5

<table>
<thead>
<tr>
<th>Project Activities</th>
<th>Monthly (February 2020 - July 2022)</th>
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<tbody>
<tr>
<td></td>
<td>Academic Year 1</td>
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<tr>
<td>Task 1: Literature Survey</td>
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<td>Task 2: Data Collection</td>
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<td>Task 3: Ground Truth Collection</td>
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<td>Task 4: Data Collection from Simulation</td>
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<td>Task 5: Develop Single Video Stream Analytics</td>
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<td>Task 6: Develop Multi-stream Video Analytics</td>
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<td>Task 7: Develop Data Fusion Methods</td>
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<td>Task 8: Hypothesis Testing</td>
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<td>Task 9: Final Report and Deliverables</td>
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March 18, 2021
CoE on Mobility and Congestion - Project 1
Lit. Survey (Task 1): Challenges and opportunities in using machine learning for traffic state estimation

- Computer Vision
  - Vehicle detection
  - Sim2real gap
  - Vehicle re-identification
  - ... and more ...

- Data Fusion
  - Video
  - Bluetooth
  - ... and more ...

- Simulation
  - Traffic
  - ... and more ...

- Existing Applications
  - Traffic signal control
  - Active traffic management
  - ... and more ...
Tasks 2 to 5: Modeling & Software Development

Closing the Sim2real gap

- Major barrier: availability of labelled data
- Solution, step 1: synthetic data
- Challenge: real-world is more complicated
- Solution, step 2: Domain Randomization

- Task 2: Data Collection
  - Procedural variation of conditions
- Task 3: Ground Truth Collection
  - Procedural geometric and other labels
- Task 4: Data Collection from Simulation
  - Accelerated collection with co-simulation
- Task 5: Develop Single Video Stream Analytics
  - ML models which will work in the real world
Scope of Work

SUMO
- Traffic simulation
  1. Different behaviors
  2. Different environments

CARLA
- Photo-realistic scene & objects
- Simulation of traffic & environmental conditions

Bluetooth Data Sequence
Loop Detector Data Seg.

VIDEO FRAMES

ML hybrid algorithm
- Data Fusion
- Parameter Estimation

Improved Traffic Signal Control
(possible extra component of theme #1)
Current Work

SUMO CONTROLS VEHICLE BEHAVIOR OUTPUTS SENSOR DATA

CARLA OUTPUTS VIDEO FRAMES, GEOMETRY, VEHICLE TYPE

Model Inference & Context-Aware Algorithms

Average speed
Density
Flow rate
... more ...

TRAINING DATA

TRAINING
VALIDATION

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Video Demo
Problems and Deviations to Date

• In general, the problem is the uncertainty that is caused by the COVID-19
• None to date
Work Planned in the Next Year

- Develop multi-stream video analytics
- Develop data fusion methods
- Hypothesis testing
- Final Report and Deliverables
Problems and Deviations Anticipated

• Real world data collection may be disrupted due to pandemic
• We have flexibility in our plans to address this disruption
NCDOT Support Needed

- Technical advice and feedback from stakeholders
Students

Catherine Spooner (FSU)
Niharika Deshpande (NC A&T)
Daniel Rundell (FSU)
Ramin Niroumand (NCSU)
Thank you!

Sambit Bhattacharya
Professor in Computer Science,
Fayetteville State University
sbhattac@uncfsu.edu
NCDOT Center of Excellence on Mobility and Congestion

Project 2
Smart Connected and Automated Vehicle Fleet Management: Developing Regional Dispatch Decision Support for Congestion Mitigation

March 18th, 2020 Center Update
Project Team

• Principal Investigator – Mary “Missy” Cummings, Ph.D.
  – Professor – Duke University
    • Department of Electrical and Computer Engineering
    • Department of Computer Science
    • Duke Robotics
    • Duke Institute for Brain Sciences
  – Director – Humans and Autonomy Lab (HAL)

• Co-Principal Investigators
  – Eleni Bardaka, Ph.D. – NC State, Assistant Professor in the Department of Civil Construction and Environmental Engineering
  – Raghavan “Srini” Srinivasan, Ph.D. – UNC-CH, Senior Transportation Research Engineer at the Highway Safety Research Center

• Senior Researcher – Nagui Rouphail, Ph.D. – NC State, Professor in the Department of Civil Construction and Environmental Engineering
Project Goals

• Develop a supervisory capability for AVs in a regional dispatch center
• Provide state and/or local authorities with monitoring of and direct communications with traditional, connected, and autonomous vehicles
• These capabilities will assist dispatcher/operators in –
  – Developing mitigation actions to reduce congestion
  – Managing planned and urgent/emergent scenarios
Duke Underlying Research Questions

- Can we adapt network optimization theory to represent connected vehicle communications?
  - Is this better than traditional optimization approaches?
  - The presence of uncertainty in the form of traditional vehicles

- How can a decision support tool based on this algorithm aid dispatchers?
  - Planning: How many and where should Road Side Units (RSUs) be located to ensure appropriate coverage/metrics?
  - Real-time: Where and when should CVs be redirected to reduce congestion?
  - Three exemplar scenarios: Minor accident at an interstate exit, major accident at interstate exchange, medical emergency in CV.
Prototype “Sketch”

- [https://www.youtube.com/watch?v=q3AFo2dmgEk](https://www.youtube.com/watch?v=q3AFo2dmgEk)
  - Figma
Prototype v1.0

• Very early in development
Thank you!

Missy Cummings
Professor and Director, Humans and Autonomy Lab, Duke University
m.cummings@duke.edu
NCSU Outline of Efforts

- Freeway Capacity Sensitivity Tool in mixed CAV, AV and TV traffic

- Surrogate safety measures (SSMs) in mixed traffic
  - Why Use them?
  - Review of Literature
  - SSM and Car-following Analysis using Real-World AV and TV trajectories in Mixed Traffic

- Future work: calibrating simulation model (SUMO) open source simulation code --- in mixed traffic
# Freeway Capacity Sensitivity Tool

## Enter Market Penetration Rate (%)

<table>
<thead>
<tr>
<th></th>
<th>CAV</th>
<th>AV</th>
<th>TV</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>30</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

## Per Lane Capacity for Indicated MPR

### OEM or User Settings for AV Time Gap (Sec.)

<table>
<thead>
<tr>
<th>Time Gap (Sec.)</th>
<th>0.50</th>
<th>0.63</th>
<th>0.75</th>
<th>0.88</th>
<th>1.00</th>
<th>1.13</th>
<th>1.25</th>
<th>1.38</th>
<th>1.50</th>
<th>1.63</th>
<th>1.75</th>
<th>1.88</th>
<th>2.00</th>
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<tbody>
<tr>
<td>0.400</td>
<td>4.105</td>
<td>3.576</td>
<td>3.352</td>
<td>3.123</td>
<td>2.956</td>
<td>2.785</td>
<td>2.650</td>
<td>2.555</td>
<td>2.466</td>
<td>2.390</td>
<td>2.314</td>
<td>2.265</td>
<td>2.213</td>
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<tr>
<td>0.700</td>
<td>3.944</td>
<td>3.514</td>
<td>3.200</td>
<td>2.962</td>
<td>2.774</td>
<td>2.623</td>
<td>2.498</td>
<td>2.393</td>
<td>2.305</td>
<td>2.228</td>
<td>2.162</td>
<td>2.103</td>
<td>2.052</td>
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<tr>
<td>0.850</td>
<td>3.897</td>
<td>3.468</td>
<td>3.154</td>
<td>2.915</td>
<td>2.728</td>
<td>2.577</td>
<td>2.452</td>
<td>2.347</td>
<td>2.258</td>
<td>2.182</td>
<td>2.116</td>
<td>2.057</td>
<td>2.005</td>
</tr>
<tr>
<td>1.000</td>
<td>3.863</td>
<td>3.433</td>
<td>3.119</td>
<td>2.880</td>
<td>2.693</td>
<td>2.542</td>
<td>2.417</td>
<td>2.312</td>
<td>2.224</td>
<td>2.147</td>
<td>2.081</td>
<td>2.022</td>
<td>1.971</td>
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</table>

## User DATA Entries

<table>
<thead>
<tr>
<th></th>
<th>CAV</th>
<th>AV</th>
<th>TV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Free Flow Speed (mph)</td>
<td>50</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Average Vehicle Length (ft)</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Time Gap Upper Bound (seconds)</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Time Gap Lower Bound (seconds)</td>
<td>0.4</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Platoon Size (vehicles)</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inter Platoon Headway Multiplier</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Headway for TV (Seconds)</td>
<td></td>
<td></td>
<td>1.64</td>
</tr>
</tbody>
</table>

## Mixed Capacity (pcphpl)

- 0 to 999
- 1000 to 1999
- 2000 to 2999
- 3000 to 3999
- 4000 to 4999
- 5000 to 5999
- 6000 to 6999

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3/18/2021
Why Use Safety Surrogate Measures (SSM)?

- Limited crash data available for AVs or CAVs
- Evaluate conflicts in the absence of limited crash data
- Conflict: observable situation in which two or more road users approach each other in time and space such that there is risk of collision if their dynamics remain unchanged.
- Use of conflict data for safety evaluation and car following rules
Review of Surrogate Safety Measures (SSMs) in Mixed Traffic

<table>
<thead>
<tr>
<th>Safety Surrogates</th>
<th>Abbreviation</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to Collision</td>
<td>TTC</td>
<td>Rear End Crash</td>
</tr>
<tr>
<td>Post Encroachment Time</td>
<td>PET</td>
<td>Right angle and Merging/Diverging Crashes</td>
</tr>
<tr>
<td>Deceleration Rate to Avoid Crash</td>
<td>DRAC</td>
<td>Rear End Crash</td>
</tr>
<tr>
<td>Time Integrated Time to Collision</td>
<td>TIT</td>
<td>Rear End Crash</td>
</tr>
<tr>
<td>Time Exposed Time to Collision</td>
<td>TET</td>
<td>Rear End Crash</td>
</tr>
<tr>
<td>Time Exposed Rear-End Crash Risk Index</td>
<td>TERCRI</td>
<td>Rear End Crash</td>
</tr>
<tr>
<td>Deceleration Rate to Avoid Crash</td>
<td>DRAC</td>
<td>Rear End Crash and Merging/Diverging Crashes</td>
</tr>
<tr>
<td>Driving Volatility (Speed/Acceleration)</td>
<td></td>
<td>Rear End Crash and Merging/Diverging Crashes</td>
</tr>
</tbody>
</table>

Review of OEM Autonomous Vehicle Dynamics Parameters

<table>
<thead>
<tr>
<th>Make/Model</th>
<th>Distance Levels</th>
<th>Range</th>
<th>Minimum Speed</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volvo</td>
<td>1-5</td>
<td>1-2.5 seconds</td>
<td>20mph</td>
<td>Adaptive Cruise Control</td>
</tr>
<tr>
<td>Tesla</td>
<td>1-7</td>
<td>Not specified</td>
<td>45mph</td>
<td>Traffic aware cruise control</td>
</tr>
<tr>
<td>Honda</td>
<td>1-4</td>
<td>1.1-2-9 seconds</td>
<td>25mph</td>
<td>Adaptive Cruise control</td>
</tr>
<tr>
<td>Mercedes</td>
<td>1-5</td>
<td>Not specified</td>
<td>15mph</td>
<td>Distronic plus</td>
</tr>
<tr>
<td>BMW</td>
<td>1-4</td>
<td>Not specified</td>
<td>20mph</td>
<td>Active Cruise Control</td>
</tr>
<tr>
<td>Hyundai</td>
<td>1-4</td>
<td>82-172 feet at 60mph</td>
<td>0mph</td>
<td>Smart Cruise control</td>
</tr>
<tr>
<td>Ford</td>
<td>1 to 4</td>
<td>82 to 150 ft at 62 mph</td>
<td>20 mph</td>
<td>Advanced Driving Assistance System</td>
</tr>
<tr>
<td>Cadillac</td>
<td>1 to 3</td>
<td>1.1 to 2.5 s</td>
<td>Not specified</td>
<td>Adaptive Cruise Control</td>
</tr>
<tr>
<td>Chevrolet</td>
<td>1 to 3</td>
<td>Up to 360 feet</td>
<td>25 mph</td>
<td>Adaptive Cruise Control</td>
</tr>
<tr>
<td>Chrysler</td>
<td>1 to 4</td>
<td>Not specified</td>
<td>25 mph</td>
<td>Adaptive Cruise Control</td>
</tr>
</tbody>
</table>
Analyze Real World Trajectories: TV/AV Mix

- Database of car-following experiments involving vehicles with Adaptive Cruise Control systems (ACC).
- ACC behavior and detailed vehicle dynamics (speed/headway/accel.) tracked
- Database contains vehicle trajectories under different car-following experiments.
- Sites in Italy, Sweden and Hungary

27 different vehicles among which 17 ACC equipped

- Controlled leading vehicle speed profile
- Two campaigns on highways and two on test beds
- Autonomous Vehicle operates in platoon with and without traditional vehicles

To access the Data Base: https://data.jrc.ec.europa.eu/dataset/9702c950-c80f-4d2f-982f-44d06ea0009f/resource/ecf3de9e-0370-431f-80ed-019b8912197f

3/18/2021
NCDOT Center of Excellence on Mobility and Congestion

Project 3
Transit and MaaS Role in Improving Economic and Healthcare Access for Underserved Populations

March 18, 2021 Center Update
Project Team

- **Kai Monast, MRP**, Director, Public Transportation Group – NCSU/ITRE
- **Noreen McDonald, Ph.D.** – Thomas Willis Lambeth Distinguished Chair, UNC-CH, Department of City and Regional Planning
- **Hyoshin (John) Park, Ph.D.** – Assistant Professor, NC A&T, Department of Computational Science and Engineering
- **Burcu Adivar, Ph.D.** – Associate Professor, Fayetteville State University, Broadwell College of Business and Economics
- **Trung Tran, Ph.D.** – Assistant Professor, Fayetteville State University, Department of Intelligence Studies, Geospatial Sciences, Political Science, and History
- **Jeremy Scott, MS** – Research Associate, Public Transportation Group – NCSU/ITRE
- **Abigail Cochran, Ph.D** – Postdoctoral Research Associate, UNC-CH, Department of City and Regional Planning
Project Goals

• How changes in health care policy (e.g. Medicaid Transformation) and transportation service delivery (e.g. Mobility as a Service- MaaS) impact:
  – Individuals
  – Health systems
  – Public transportation
• How transport system innovation impacts health care access by:
  – Modeling existing services
  – Developing operational scenarios
  – Analyzing patient travel preferences based on the scenarios
  – Assessing information needs for patients and care managers
  – Building a decision support tool
Methodology

• Mixed methods research focusing on people and institutions in the Elizabeth City area as they experience disruptions
  • COVID-19
  • Medicaid Transformation
  • Mobility-as-a-Service Technology and Access Enhancements
• Spatial and Tabular Data analysis
• Surveys and interviews of individuals and healthcare providers
• Modeling to assist with implementing accessibility improvements
Spatial and Temporal Data Analysis

April 2019 Trips

April 2020 Trips
Weekly Stops at Non-Home Destinations Pre COVID (4/2019)

Weekly Stops at Non-Home Destinations Peak COVID (4/2020)

Note: Class breaks were done by quintile classification. Every class has 10% of all destinations.
Peak periods for stop activity

Note: Class breaks were done by quintile classification. Every class has 10% of all destinations.
Spatial Distribution of Stops at Non-Home Destinations Pre COVID (4/2019)

- All stops at non-home destinations Pre COVID
- 75% of stops were between 8:00am - 12:00pm and 2:00pm - 3:00pm
Spatial Distribution of Stops at Non-Home Destinations Peak COVID (4/2020)

- All stops at non-home destinations Peak COVID
- 75% of stops were between 5:00am - 6:00am, 9:00am - 11:00am, and 5:00pm
Surveys and Interviews

Addressing Transportation Barriers to Health Care During the COVID-19 Pandemic

Between October and November 2020, in-depth interviews were conducted with sixteen (16) nurses, social workers, and other professionals in North Carolina who help address health-related social needs. The interviews identified the transportation barriers to health care that individuals have encountered during the pandemic, and solutions medical systems have used to address these challenges. This infographic summarizes the key findings.

EXISTING TRANSPORTATION BARRIERS EXACERBATED

Financial strain and transportation service changes built upon existing transportation barriers (e.g., cost and availability of transportation options, etc.).

PANDEMIC CREATED NEW BARRIERS

Concerns emerged about COVID-19 exposure while traveling with strangers, particularly public transportation use and ride-hailing.

“At times, [riders] may have social anxiety… with COVID, folks do have a little increased anxiety about riding public transportation.”

- Care Coordinator in Albemarle Region
Modeling

- Baseline model development
- Develop assumptions
- Integration of Medicaid trip data and Transmodeler simulation
- Analyze the spatiotemporal patterns of service performance
Next Steps

• Continue to develop analytical tools
• Continue surveying individuals and healthcare providers
• Finalize model data and parameters
• Conduct pre- and post-analytics for all time periods
• Develop service alternatives
• Conduct stated-preference surveys of the alternatives
• Publications, presentations, and final report
Questions?

- Kai Monast – NCSU/ITRE, kai_monast@ncsu.edu
- Noreen McDonald – UNC-CH, noreen@unc.edu
- Hyoshin (John) Park – NC A&T, hpark1@ncat.edu
- Burcu Adivar – FSU, badivar1@uncfsu.edu
- Trung Tran – FSU, ttran1@uncfsu.edu
- Jeremy Scott – NCSU/ITRE, jscott@ncsu.edu
- Abigail Cochran – UNC-CH, acochran@unc.edu