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Social intelligence for autonomous vehicles interacting with vulnerable road users

Protecting vulnerable road users (VRUs) has always been a top priority in intelligent transportation research. Safety-oriented pre-collision systems have been developed and implemented for vehicles with lower automation levels to protect vulnerable road users via kinematics-based crash calculations. Many research efforts, including naturalistic driving study and standardized system evaluation, have been made to ensure the performance of such safety functionalities. Although the warnings and automatic emergency braking systems can efficiently reduce crash injuries, they cannot support higher-level autonomous vehicles interacting with VRUs and driving efficiently without human interventions in urban settings. Numerous algorithms predicting pedestrian trajectories and future actions have been developed in the past several years, which still cannot fully solve the VRU interaction dilemma. In this presentation, we discuss the importance of social intelligence for autonomous vehicles, emphasizing the capability to estimate and negotiate intentions with VRUs for effective and safe interactions. We will highlight the differences between intention and existing behavior predictions, especially regarding autonomous vehicles' motion planning during vehicle-VRU interactions. A series of research efforts conducted in the Transportation & Autonomous Systems Institute (TASI) at IUPUI will be presented related to developing intention prediction algorithms and benchmark datasets for all types of VRUs. We will propose and discuss open challenges for developing autonomous vehicles with social intelligence.

Social Intelligence for Autonomous Vehicles Interacting with Vulnerable Road Users

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Background

- Protection of VRUs is vital for reducing injuries and fatalities and enhancing road safety
  - Pedestrians
    - >7,400 pedestrians were killed in US in 2021
    - Highest in the past 4 decades
    - Pedestrian fatalities increased >50% from 2010 to 2021
  - Other VRUs, especially the quickly increased e-scooter riders
    - The use of micromobility options increases
      - Over 200,000 e-scooters by 2020 in 100 cities,
        - 38 million trips taken on these e-scooters
    - Increased crashes
      - 4,800 e-scooter injuries in 2014 -> 29,000 in 2018
      - About 20–25 ER injuries every 100,000 e-scooter trips

VRU Protection with Automated Driving Technologies

- Traditional technical solution
  - Pedestrian crash avoidance system
    - Pedestrian detection and tracking
    - Short-term kinematics-based trajectory prediction
  - Typical Functions
    - Pre-collision warning
    - Automatic emergency braking
      - e.g., Toyota Pre-Collision System with Pedestrian Detection
    - Collision mitigation steering
      - e.g., Honda SENSING Pedestrian Collision Mitigation Steering System

VRU Protection with Automated Driving Technologies

- Many research and development efforts have been made on the pedestrian-safety-oriented systems.
  - Pedestrian behavior modeling

TASI 110-car Naturalistic Driving Study

- 116 drivers in Indy Metropolitan area
- Continued scene videos and GPS
- 12 months with ~1.44 million miles
- 62k pedestrians and 13k cyclists labeled for the total 40k hours of driving

VRU Behavior Modeling

- Representative crash testing scenarios
  - Naturalistic driving data + crash data
- VRU characteristics
  - Movement metrics
  - Appearances
  - Environment conditions

Data Collection Device

Collected Video Data

VRU Protection with Automated Driving Technologies

- Standardized vehicle system testing

Interactions with VRUs for Automated Driving

- For higher-level automated driving, safety-oriented pedestrian crash avoidance is not sufficient.
  - Longer response time
  - Non-verbal interaction/negotiation
  - Sudden change of pedestrian behavior
- Predicting pedestrian behavior is critical for ADS to improve safety and ensure traffic efficiency in urban settings.

State-of-the-Art Pedestrian Behavior Prediction Research

- Pedestrian action anticipation
  - Predicting an action before it happens or recognizing an action at very early stage
- Pedestrian trajectory prediction
  - Mapping a sequence of observed pedestrian locations into a sequence of future locations
- Pedestrian crossing intention prediction
  - not well defined, usually surrogated by trajectory prediction and crossing action

Social Intelligence for Automated Driving Interacting with VRUs

- Intuition
  - Pedestrian Intention ≠ Pedestrian Behavior


+0s


+3s


+5s


+8s

Time


+0s


+2s


+3s


+4s

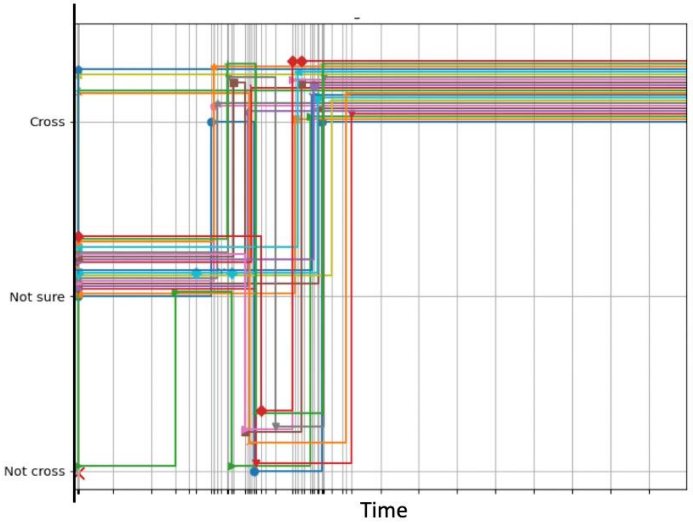
  - Intention-based motion planning is necessary

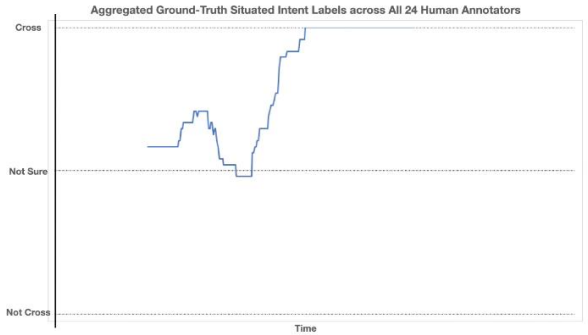
Pedestrian Situated Intent (PSI)

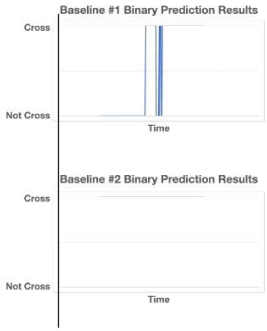
- PSI is defined as the pedestrian intent to cross in front of the ego-vehicle in the dynamically changing situations involving the car, pedestrian, and contextual environment.
  - Directly measure pedestrian mental states
  - Explain pedestrian behaviors during interactions
  - Improve and supplement pedestrian action and trajectory predictions
  - Support the planning of social actions of the ADS

IUPUI-CSRC-PSI Dataset

- Link: http://situated-intent.net/pedestrian_dataset/



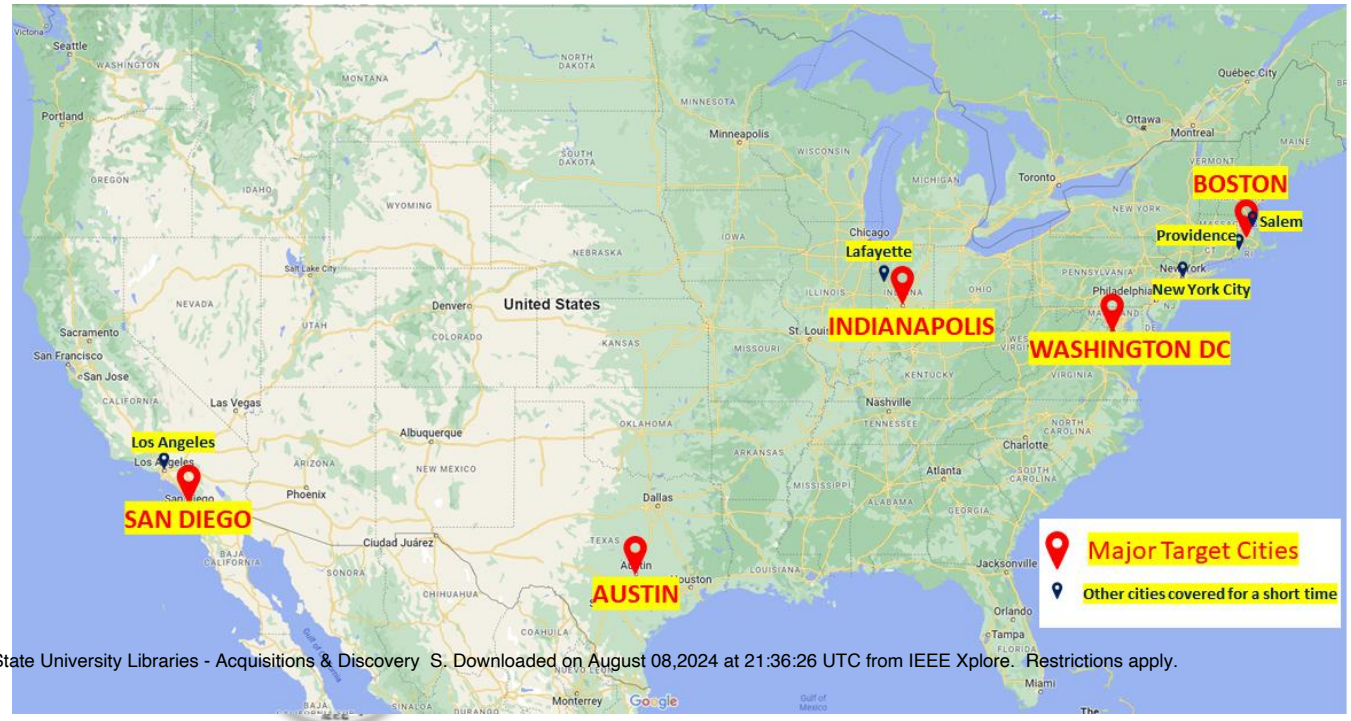




PSI + Trajectory Prediction

Situated Intents for All VRUs

- Naturalistic data collection in 4 US Regions
  - All VRUs (Pedestrians, E-scooter Riders, Bicyclists in 200 hours of driving)
  - Global scene reconstructions (LiDAR + 360 Camera + RTK GPS)
  - Comprehensive annotations (Visual, Map, and Intent labels)



Summary

- Interactions with VRUs are challenging for current automated vehicles
- Main research issue:
  - VRU intention prediction is not well defined, usually surrogated by trajectory prediction and crossing action
- Solutions and future direction:
  - Social Intelligence is important for automated vehicles to interact with VRUs
  - Situated-intent-supported vehicle motion and social behavior planning shall be further investigated

Thank You!

Questions?

Renran Tian and Yaobin Chen" Social intelligence for autonomous vehicles

- Suddenly, came the escooters 😊 around 2018
- Pedestrian manican standards for lidar and radar, and camera
- How to predict intent
- You need Higher reponsie time, better negotiation, etc
- To make the prediction longer, people use AI, machine learning, etc.
- Behavior is not enough, we need to estimate intention
  - Behavior depends on intention and cost
- Pedestrian situated intent (PSI)
- Open source data, asked peds to provide text description of their intentions

Discussion

- Saeed: why worry about pedestrians. Will impose a very high level of confidence we need to reach in the system. When would it give me high level of confidence?
  - Not suggesting cars would do the same thing. Cars only decelerate (always conservative). Give warning to driver that ped might intend to do something. Identify when ped doesn't even want to go, so the car has to recognize that.
- Weibin: ow to apply this technology. Soe states don't save traffic data to avoid liability. Especially when you mention social.
- Does this use data from vehicles as well
  - Yes. Consider up to 36 object from the scene, crash movement
- Side comments: all features in cars are tied to confort and convenience, etc. (saied RESPONIDING TO pETROS)

Dr. Yaobin Chen is a Chancellor's Professor of electrical and computer engineering and the Founding Director of the Transportation and Autonomous Systems Institute (TASI) in the Purdue School of Engineering and Technology, IUPUI, Indianapolis, IN, U.S.A. He received his BS degree from Nanjing Institute of Technology, Nanjing, China in 1982, MS and Ph.D. degrees from Rensselaer Polytechnic Institute, Troy, New York, in 1986 and 1988 respectively, all in electrical engineering. From 1988 to 1990, Dr. Chen was a visiting assistant professor of electrical engineering at the George Washington University, Washington, DC. Since 1990, Dr. Chen has been with the Purdue School of Engineering and Technology, IUPUI, where he served as Associate Dean for Research from 2003 to 2005 and Chair of the Department of Electrical and Computer Engineering from 2005 to 2015.

Dr. Chen's areas of research interest include intelligent transportation systems, automated vehicles, EV and HEV, intelligent controls and robotics. He has published 190 technical papers in refereed journals and conference proceedings in his field of research. He is a co-inventor of 10 U.S. patents. He was a recipient of the National Science Foundation Research Initiation Award in 1991. Dr. Chen is a senior member of IEEE and a member of SAE. He has served in many leadership positions in his professional service and activities including Vice President of Technical Activities and Vice President of Administrative Activities for the IEEE ITSS; a Senior Editor for the IEEE Trans. on ITS; and General Chair of the IEEE ITSC 2021.

Dr. Renran Tian is an assistant professor in the Department of Computer Information Technology at Indiana University-Purdue University Indianapolis (IUPUI). He earned his Ph.D. in Industrial Engineering from Purdue University in 2013 and holds a B.S. and M.S. in Mechanical Engineering from Tsinghua University in Beijing, China. Dr. Tian's research interests are focused on human-centered computing, human-AI interaction, cognitive ergonomics, human computation, and autonomous driving. Throughout his career, he has secured over $3M in funding as principal investigator from the National Science Foundation (NSF), the Indiana Department of Transportation, and other automotive industry sponsors. Dr. Tian is a prolific author with over 50 peer-reviewed publications in top-tier journals and conference proceedings. He serves as the chair of the Technical Committees on Human-Centered AI in Transportation for the IEEE Intelligent Transportation Systems Society and is responsible for organizing the "Prediction of Pedestrian Behaviors" workshop series. Additionally, he has served as an organizing committee member, associate editor, and session chair for more than 30 international conferences. Dr. Tian was recognized with the NSF CAREER Award in 2022 for his research on modeling pedestrian situated intent.