Seventh Annual
Cyber-Physical Systems Principal Investigators' Meeting
Arlington, VA | October 31 – November 1, 2016

EAGER: A Unified Solution of Mixed Traffic Sensing, Tracking and Acceptable Active Accident Avoidance for On-Demand Automated Shuttles in a Smart City

Pis: Ümit Özgüner, Keith Redmill, Bilin Aksun Güvenç
with Michael Vernier, Xiangjun Fu, Arda Kurt

NSF CPS PI Meeting 2016
Arlington, VA

THE OHIO STATE UNIVERSITY

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SMOOTH: Smart Mobile Operation: THE OHIO STATE UNIVERSITY Transportation Hub On Demand AUTOMATED SHUTTLES

Keith Redmill, Bilin Aksun Guvenc, Umit Ozguner - The Ohio State University

Challenge:

- Most people in the US do not live or work close to a transportation stop – first mile / last mile problem
- Walking does not apply to everybody - elderly people, handicapped people, people with luggage
- Elderly people are expected to become 20% of the entire US population in 25 years

Solution:

- On demand automated shuttles
- Smartphone app used for reserving space in an automated shuttle
- Shuttle timing has to be coordinated with the bus arrival and departure
- Connected Vehicle technology (intersection safety, cooperative driving)

EAGER: A Unified Solution of Mixed Traffic Sensing, Tracking and Acceptable Active Accident Avoidance for On-Demand Automated Shuttles in a Smart City
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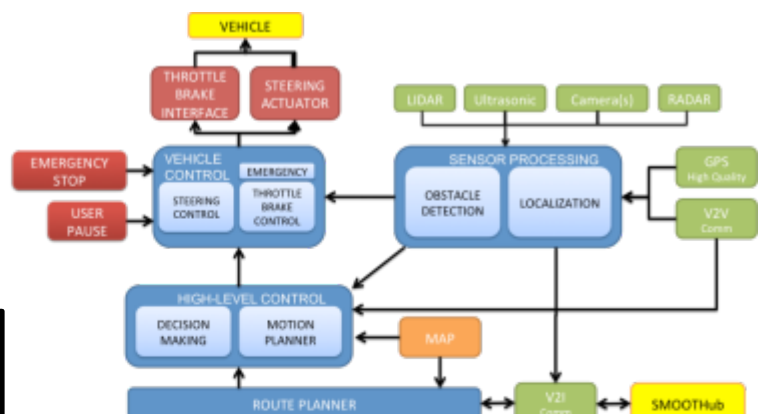


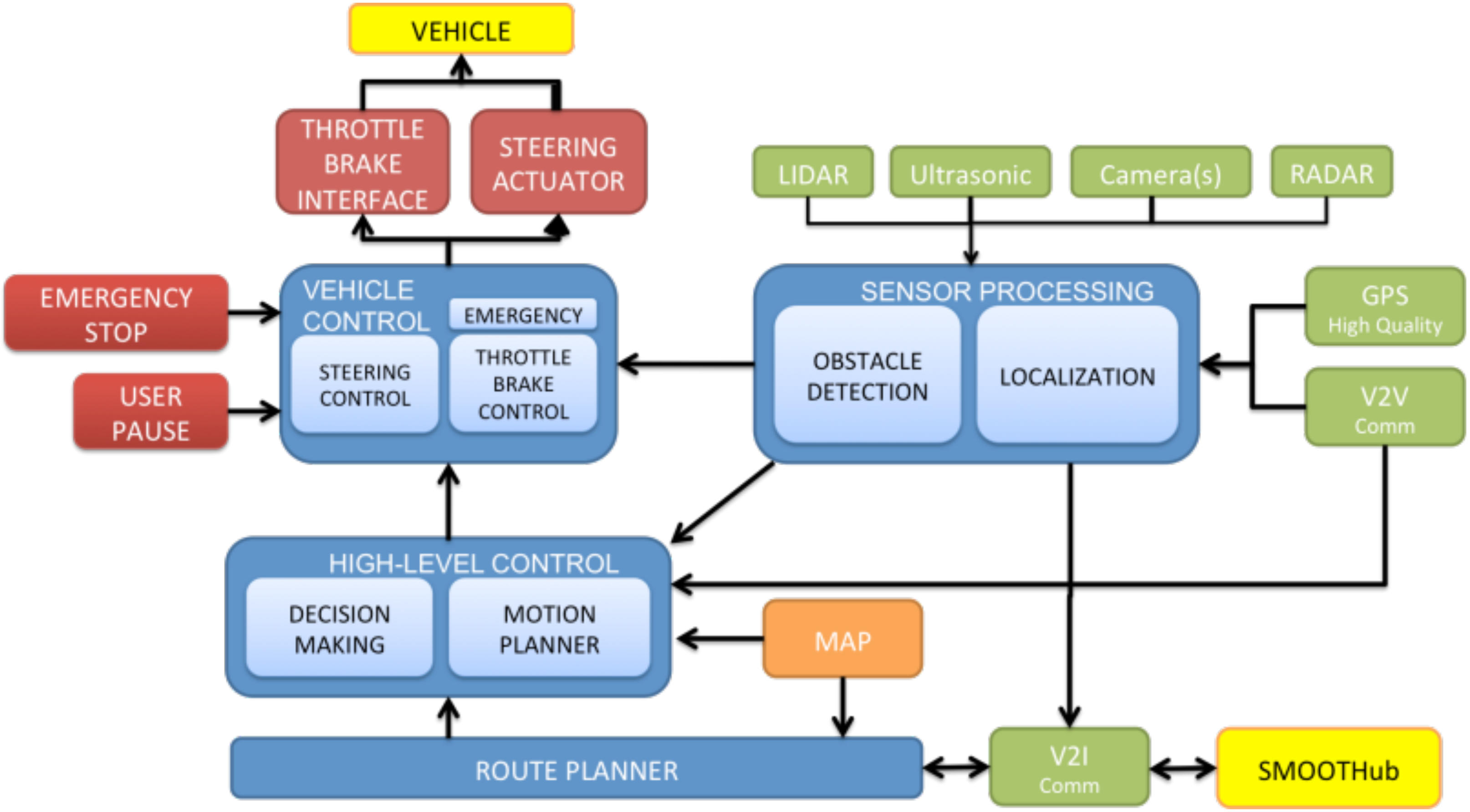
Scientific Impact:

- Development of a unifying theoretical framework for sensing and tracking in densely crowded situations will benefit a larger class of CPS in transportation
- Pedestrian motion models will affect both automated vehicles and the larger smart cities and city planning efforts.

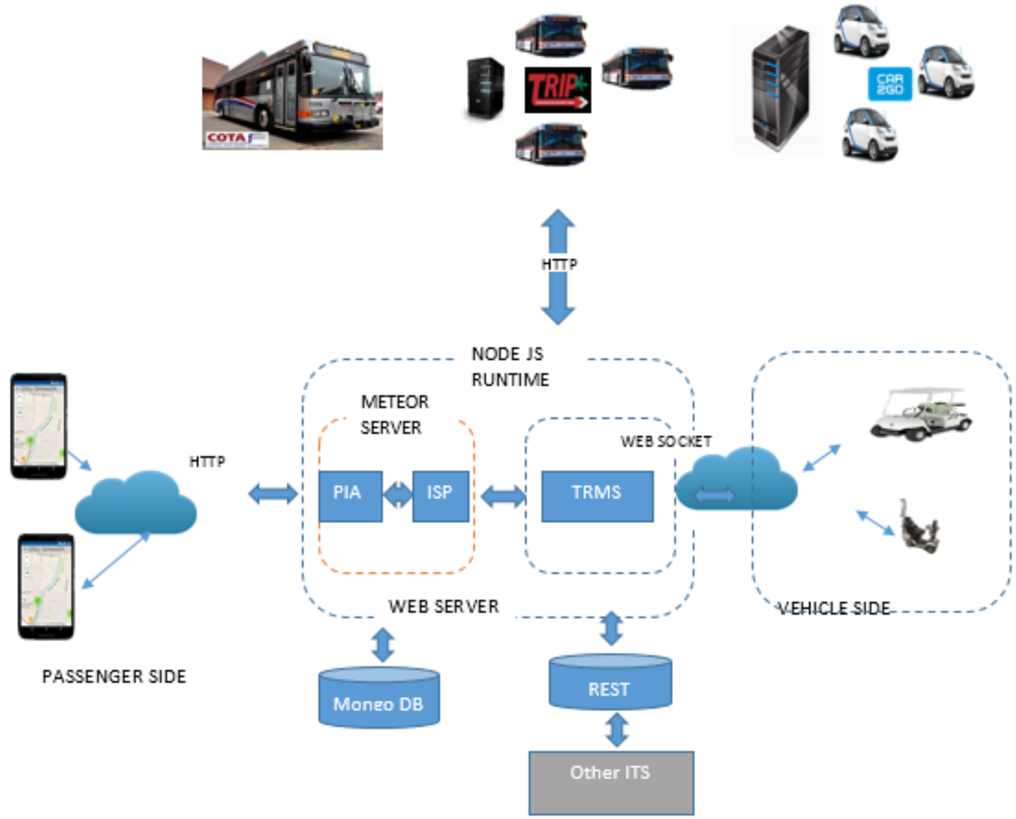
Broader Impact:

- Increased mobility for the elderly or mobility impaired individuals
- People who need easier access to the rest of the transportation network (public/shared/ private)
- An excellent testbed and teaching tool for Transportation CPS, ITS, automated vehicles

General architecture for individual vehicles



- Designed as a web architecture, utilizing a cloud-based application platform called Meteor, which can be accessed from desktops and mobile devices.
- Deployed as a multi-tier web system.
- Cooperates with other transit modes by integrating its services to make a multi modal transit plan.



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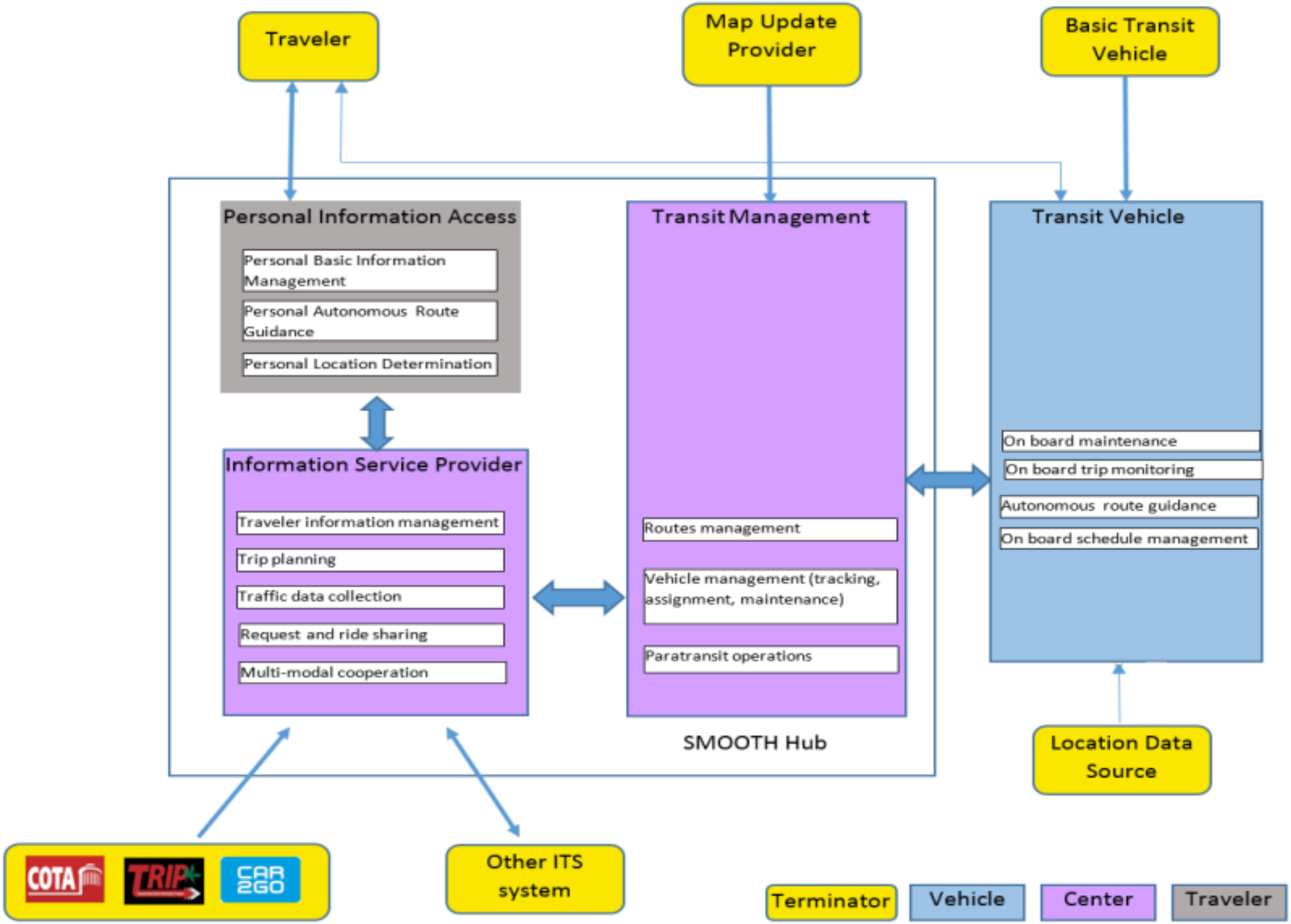
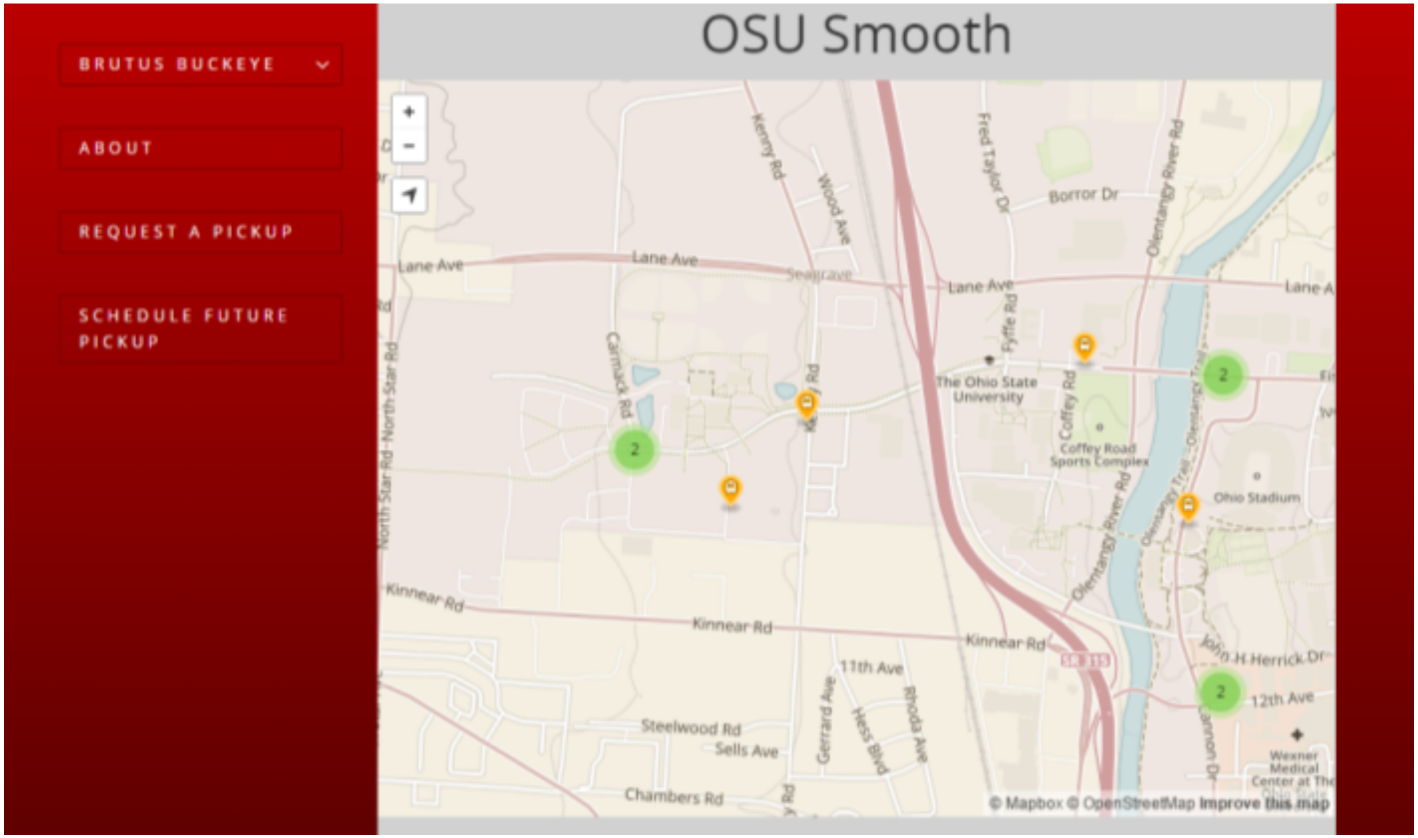
Fits within the national ITS Architecture



SMOOTH Web Portal

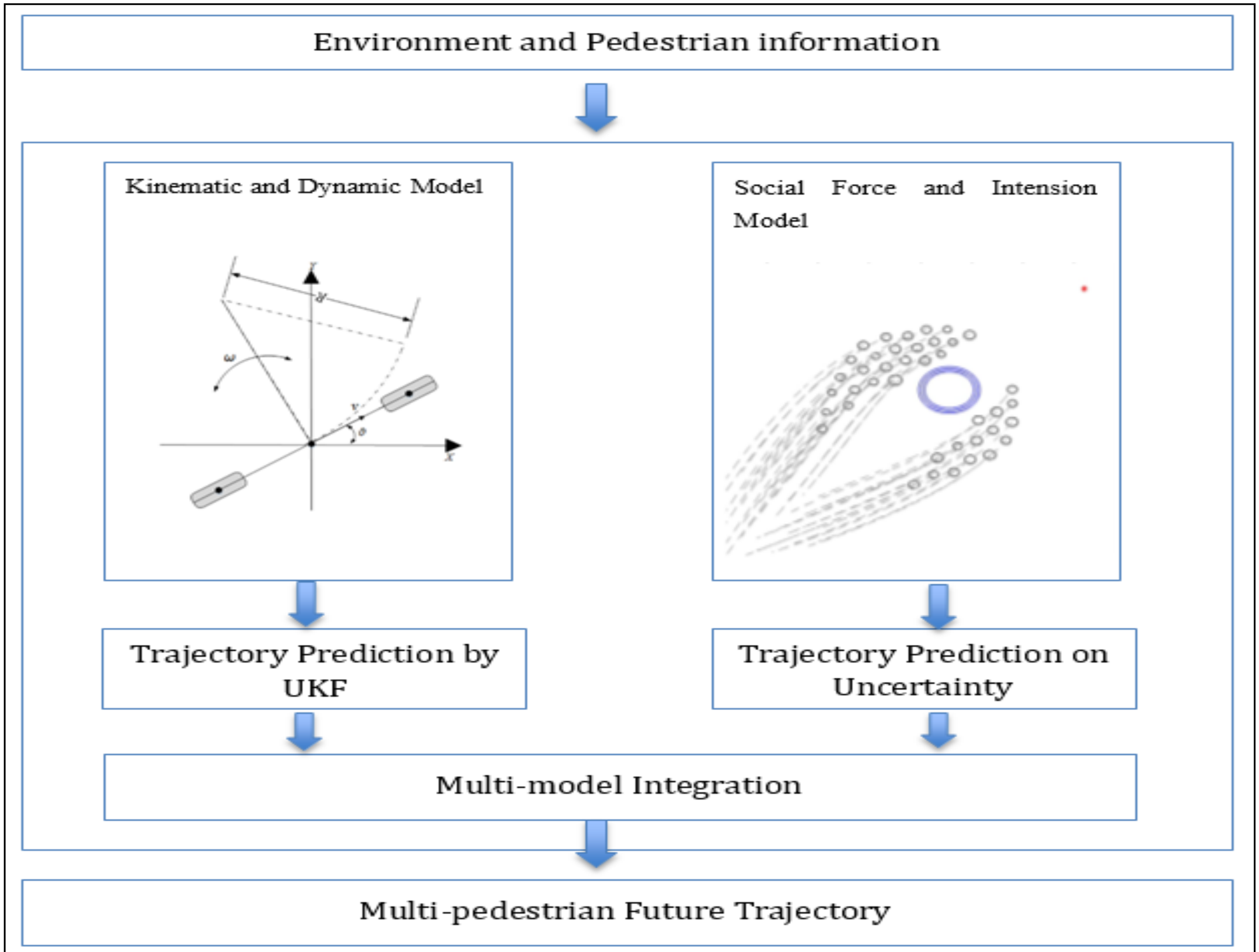


Features: Request an immediate pickup, Schedule a future pickup, Real-time autonomous vehicle status information, Administrator view for system status information, User authentication, Geo-location for pick up location, Map view provided by MapBox/ OpenStreetMap, Real-time OSU CABS bus information, Mobile compatible layout for easy viewing on a smartphone or tablet

Dense, pedestrian-rich environments

- **Problem:**
  - It is difficult to predict trajectories of pedestrians, due to highly dynamical movement of pedestrians and crowd traffic: sidewalks, pedestrian crossing
  - "Collision imminent" (pedestrian in front of vehicle) check is not sufficient.
- **Solution:**
  - An agent based Pedestrian/Crowd Motion Modeling method to simulate the social forces and intensions to predict long-term pedestrian paths
  - An integrated pedestrian trajectory prediction approach is designed. It combines kinematic and dynamic aspects of the model, the agent based social force interactions and Intention-aware models

Dense, pedestrian-rich environments



Pedestrian / Passenger Models

Pedestrian Simulation Approaches

- Macro Simulation
  - Fluid Dynamics
- Micro Simulation
  - Cellular Automata
  - Social Forces
  - Agent-based Methods

- Agent-based Methods:
  - Advantages:
    - Agents can be given internal states (e.g. intentions, high-level behaviors, perceptions, preferences) allowing actual agency—as opposed to merely apparent one (as in other approaches).
    - Agent models can incorporate a wide range of psychological factors (due to modeling flexibility)—which leads to more realistic simulations.
  - Disadvantages:
    - Agent-based simulations result in higher computational complexity—which limits their areas of applicability to small-to-medium scale simulations. (However, in our targeted applications, the computational complexity remains within an agreeable range.)

Social Forces: Doors, Walls, People

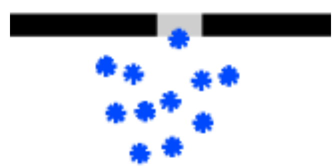
$$F^{(i)} = F^{(i)}_{door} + F^{(i)}_{people} + F^{(i)}_{wall}$$

$$F^{(i)}_{door} = F^{(i,d)}_{att} + q^{(i,d)} F^{(i,d)}_{rep}$$

$$F^{(i)}_{people} = \sum_{j \in P_1} F^{(i,j)}_{imm} + \sum_{j \in P_2} F^{(i,j)}_{flow}$$

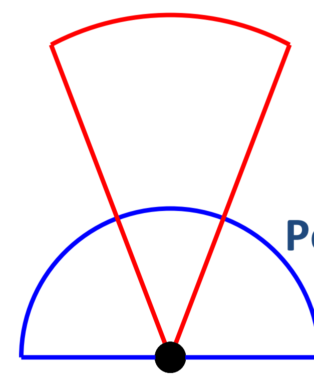
Doors:

- Pedestrians are attracted towards their selected door.
- If they are waiting in the queue, a repulsive force is also active to keep them at a minimal waiting distance.



People:

- Pedestrians are repelled by other pedestrians within their peripheral vision.
- Pedestrians are repelled by other pedestrians within their central vision who are moving in opposite direction.
  - ➢ They proactively avoid approaching flows and demonstrate lane forming behavior.



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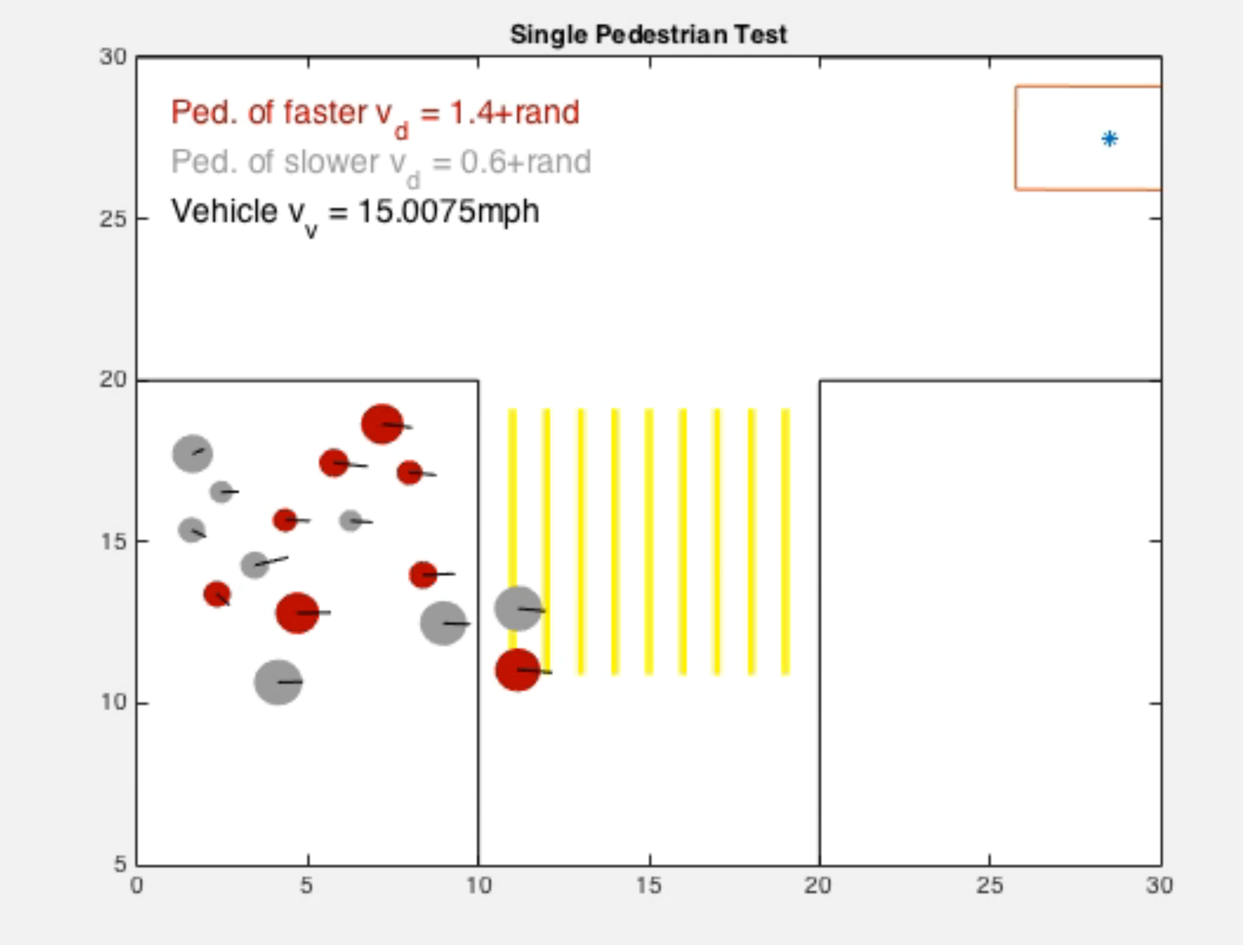
Single Pedestrian Test
Ped. of faster v_d = 1.4+rand
Ped. of slower v_d = 0.6+rand
Vehicle v_v = 15.0075mph
30
25
20
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10
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5
10
15
20
25
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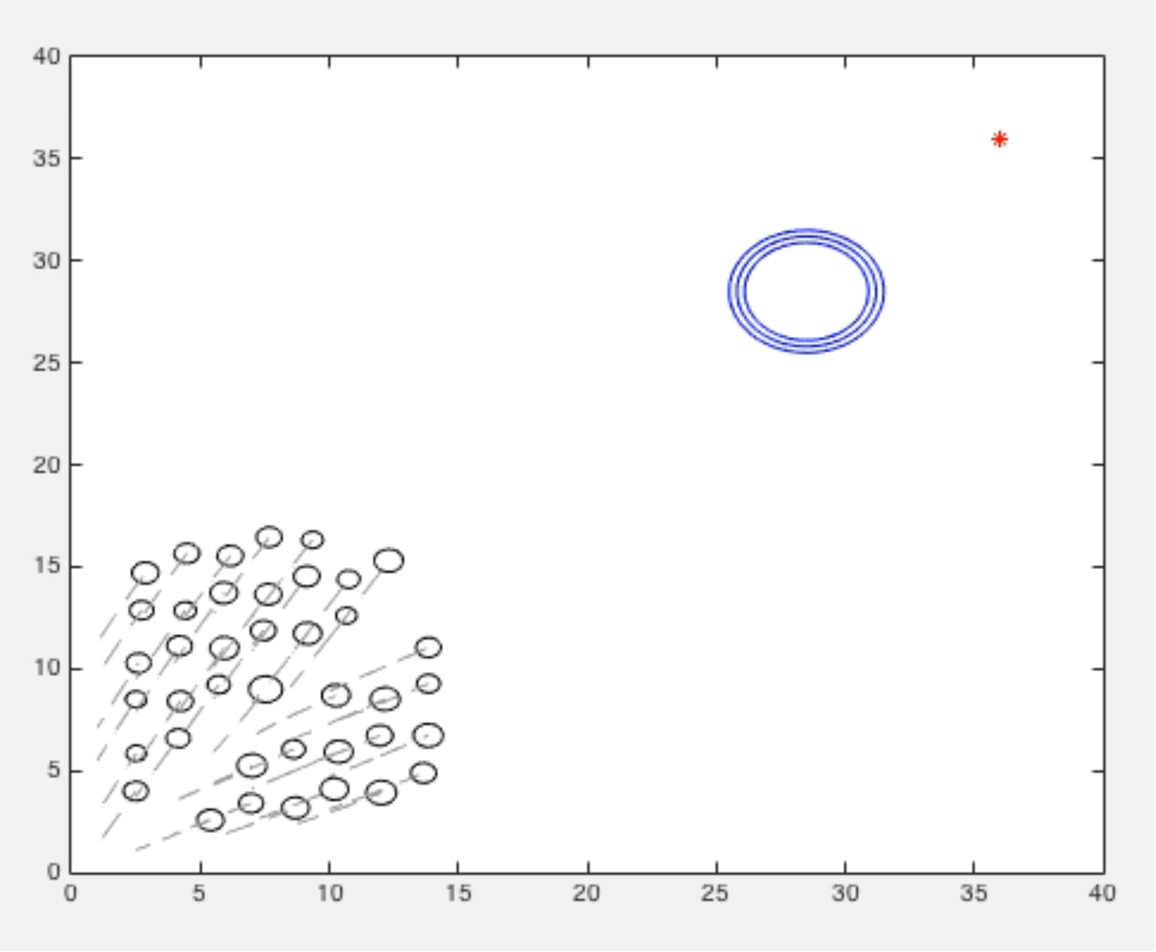
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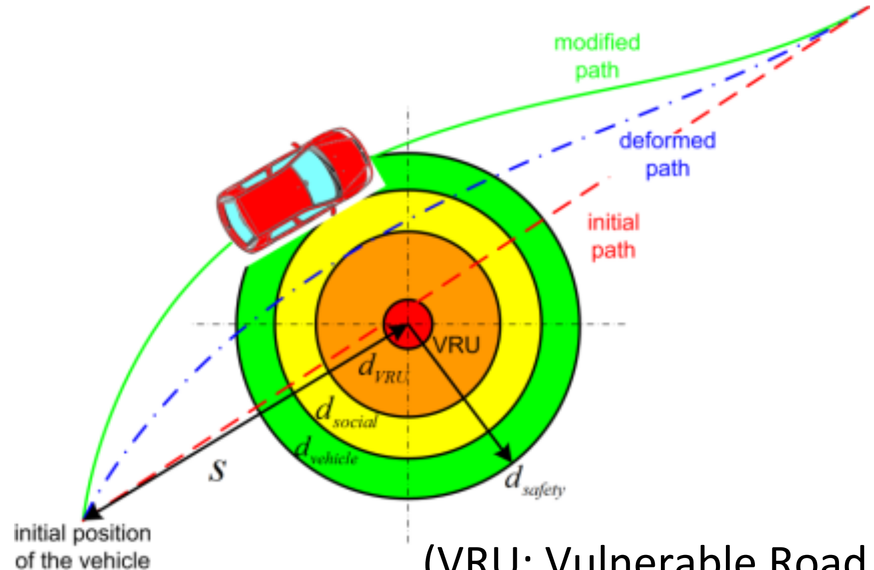
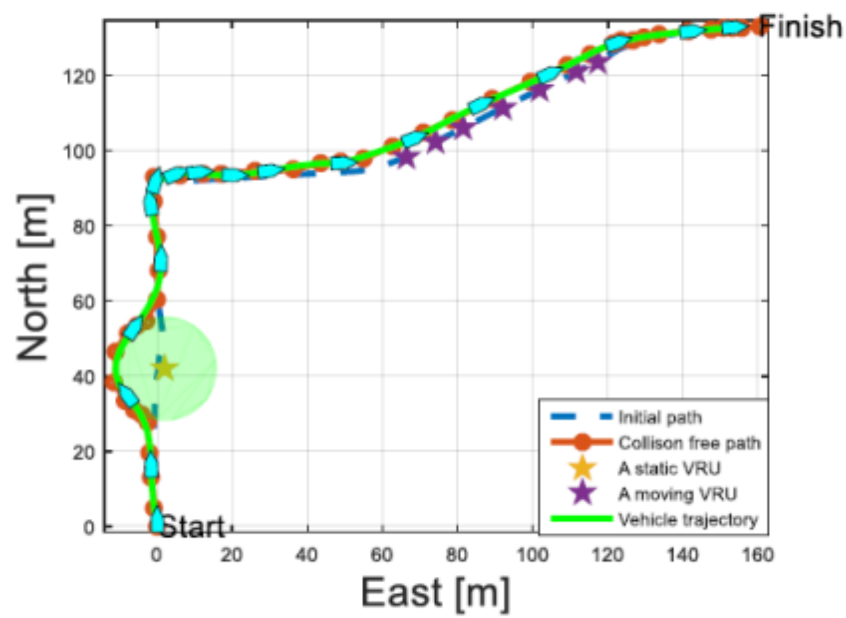
Socially Acceptable Collision Avoidance

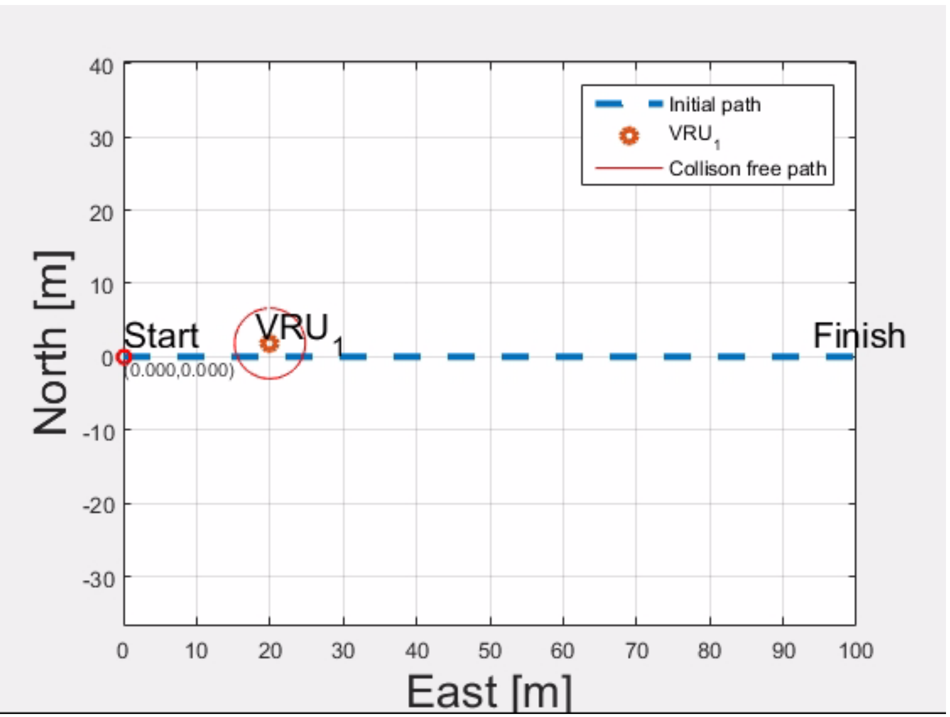
The socially acceptable collision avoidance method based on elastic band theory has been developed and demonstrated in highly realistic simulations. It has been tested in real time.



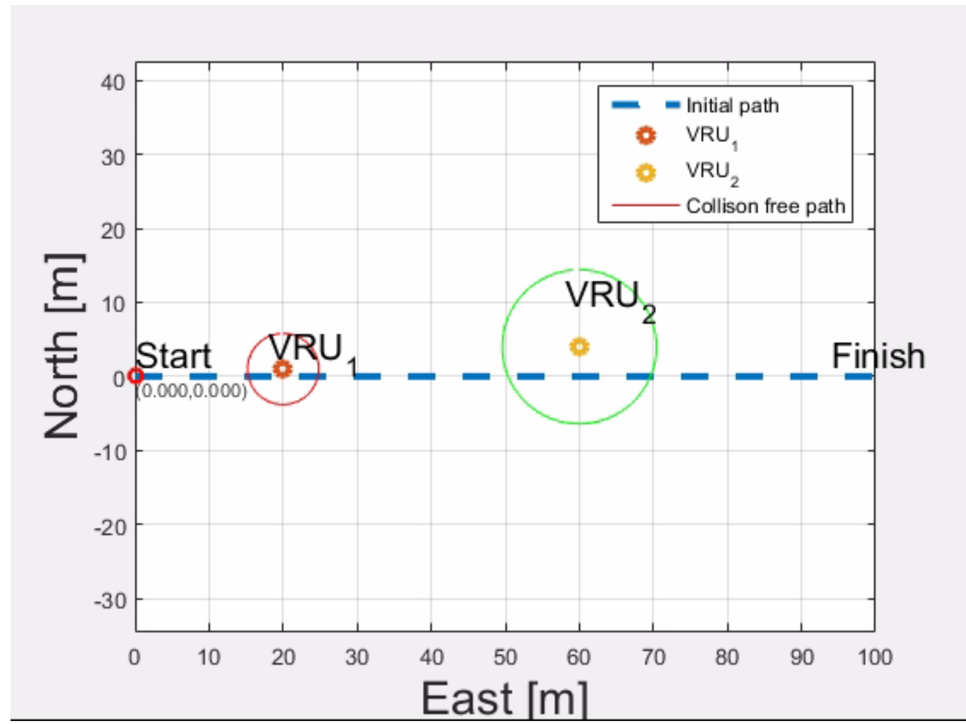
(VRU: Vulnerable Road User)



Simulation Animation Examples of SACA Algorithm

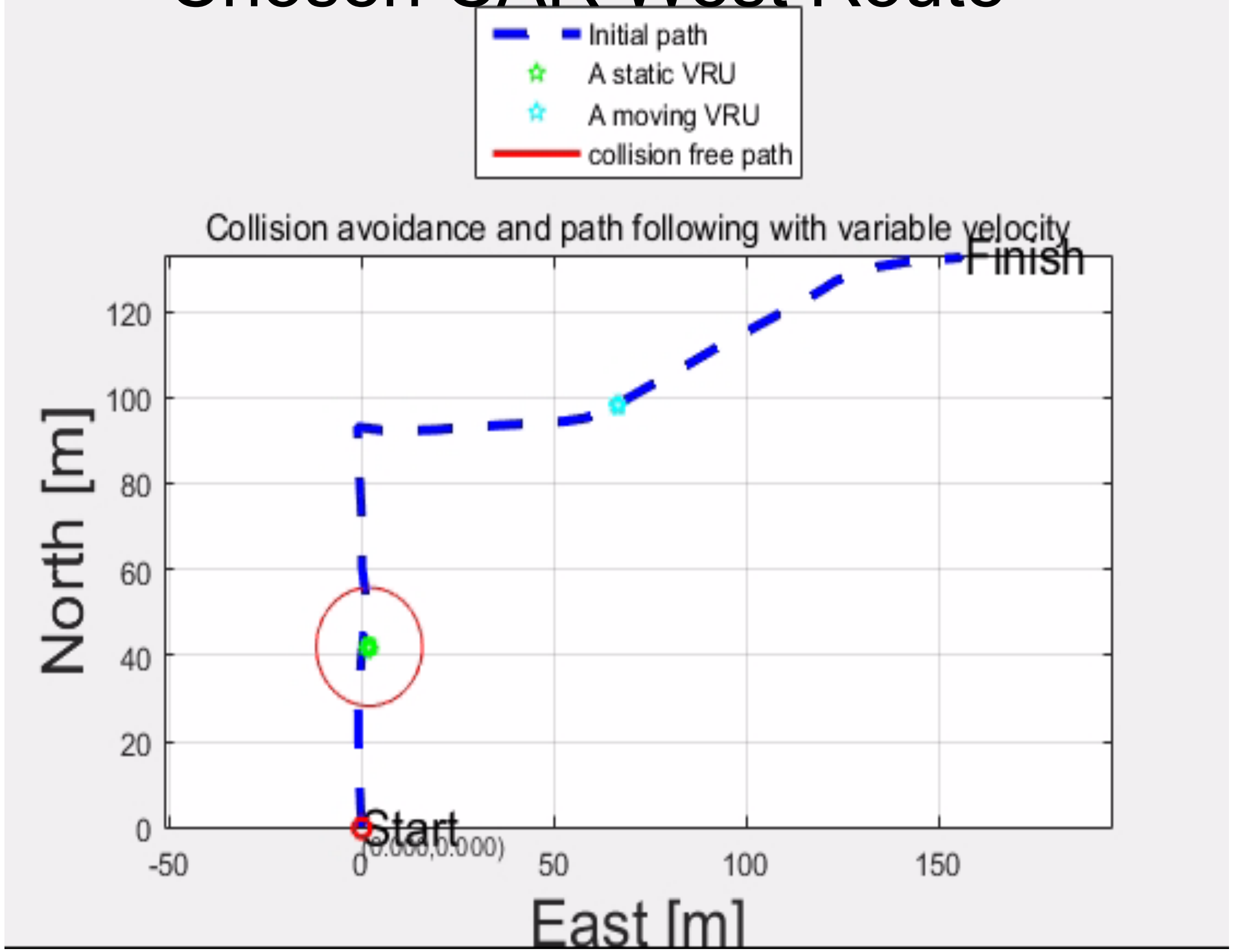


SACA algorithm with one static VRU



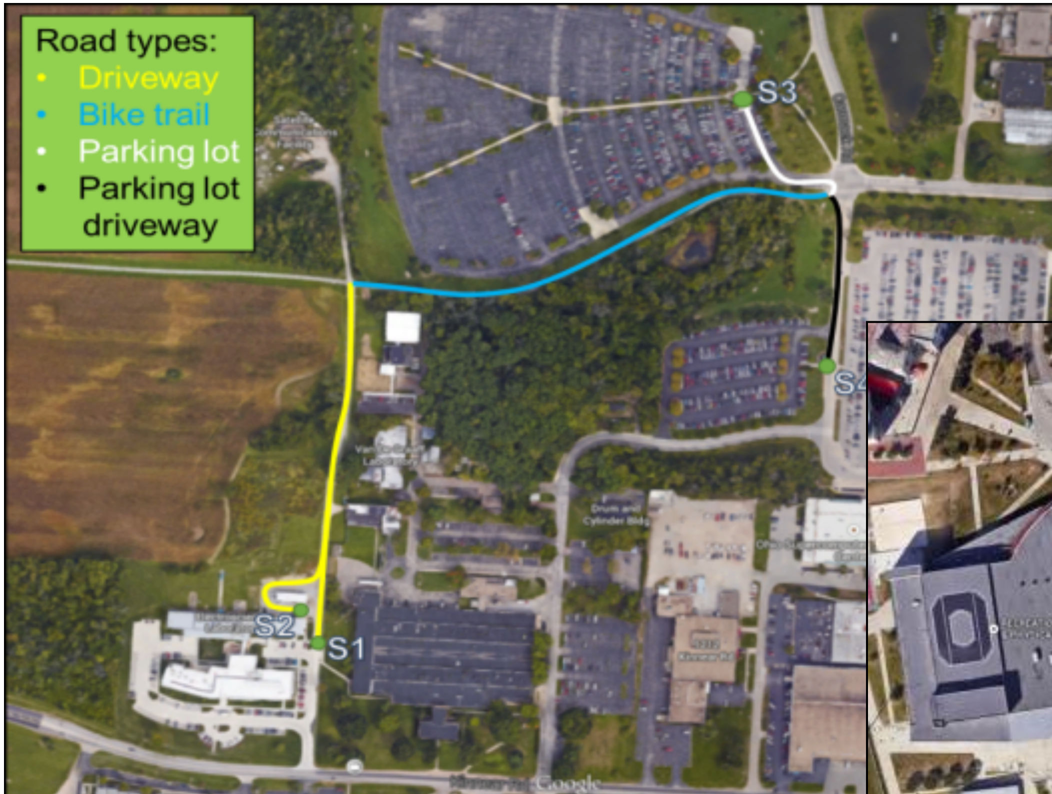
SACA algorithm with two static VRUs

Simulation Animation of SACA Algorithm on a Chosen CAR West Route



SACA algorithm with both static and moving VRUs

Pilot Routes



Planning a demo on a university campus is not easy

OSU Offices Involved

- Research Compliance
- Legal Affairs
- Transportation and Traffic Management (TTM)
- University Compliance and Integrity
- Public Safety (DPS)
- Facilities and Operations
- Risk Management

Requirements

- There needs to be a licensed driver in the vehicle at all times
- Tests will only occur during daytime hours
- Some routes will require either DPS or TTM officer support:
  - DPS officers: 3-4 week advanced notification, 3 hour minimum, at overtime rate
- TBD:
  - Who owns/controls the bike paths
  - If the parking permit company need to approve
  - Taking videos: any issues with filming on campus
  - Do golf carts need license plates?
  - Signs on the bike path

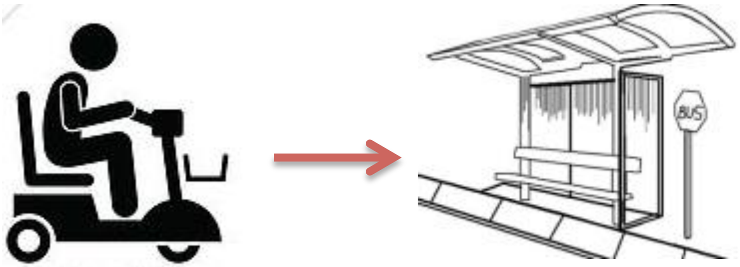
• General Operation / Demo description

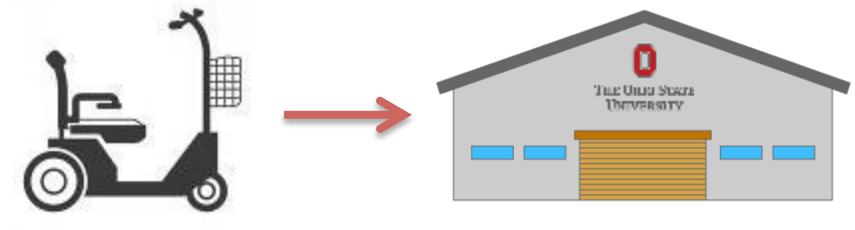
- Using the SMOOTH smartphone app, the passengers:
  - Check the local public transportation options and schedules (OSU bus system or City of Columbus bus system)
  - Select a pick-up node and a drop-off node in the SMOOTH network based on where they are and the desired bus stop
  - Schedule a type of vehicle and a pickup time

- SMOOTH central hub and dispatch system receives the request from the smartphone app

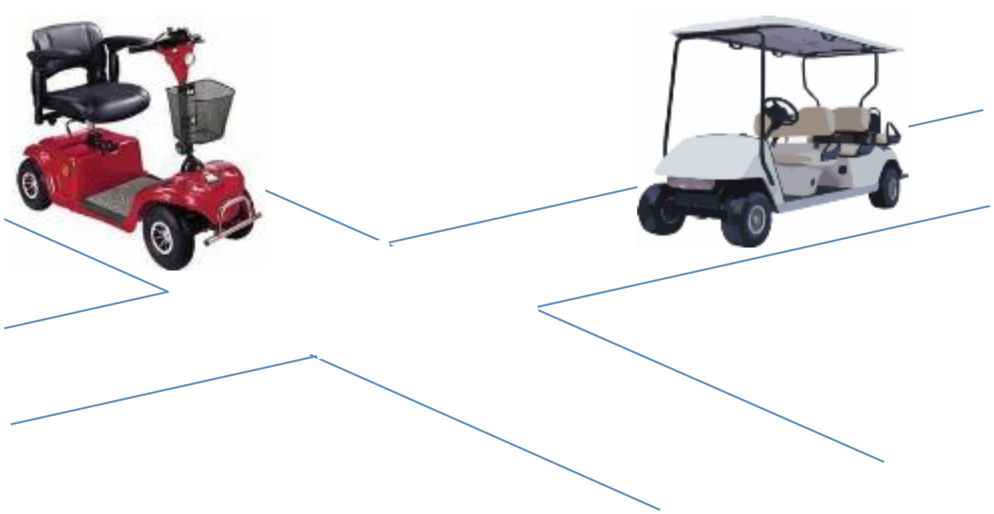
- The selected type of SMOOTH vehicle is dispatched to the passenger pick-up node at the designated time.

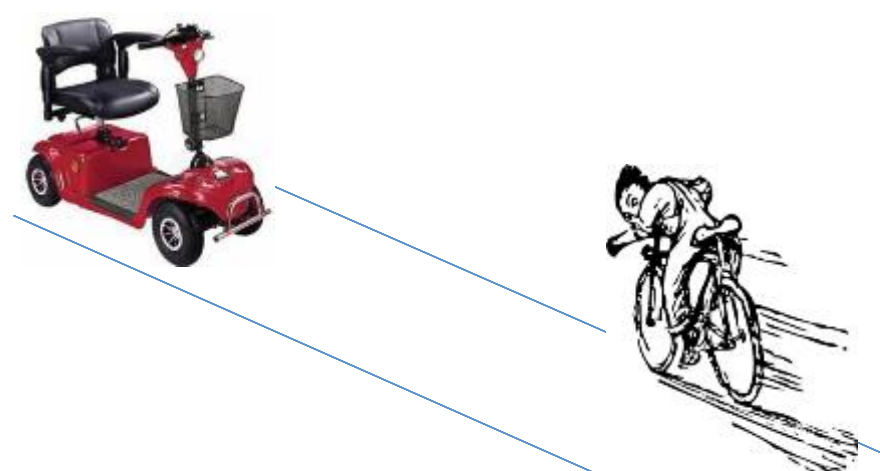
- All the vehicles are tracked by the central hub over wireless communication.
- Once dispatched, the vehicles control themselves – automated navigation is locally controlled.





- The SMOOTH vehicle autonomously takes the passenger to the selected drop-off node (the bus stop), and if there are no other tasks from the dispatch, returns to the central hub.
- The vehicles use vehicle-to-vehicle communication and on-board sensors to navigate through intersections, avoid obstacles, and share the road with pedestrians and bicycles





- Demo video