A Connected Work Zone Hazard Detection System for Roadway Construction Work Zones

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Highway Construction Safety

Fatal Injury Facts

- 24,745 individuals (about 750 per year) lost their lives in work zone crashes (1982-2014).

- 1571 deaths related to highway construction (2003-2015).

- Highway work zone fatality occurs every 8.7 hours.

- A work zone crash occurred once every 5.4 minutes.

Current Preventive Measures

- Building safer highway work zones:

  Measures to prevent worker injuries from vehicles and equipment (2001, NIOSH)

- Work zone intrusion alarm technology (WZIAT)

- Crash detection inside work zone

SonoBlaster® Work Zone Intrusion Alarm
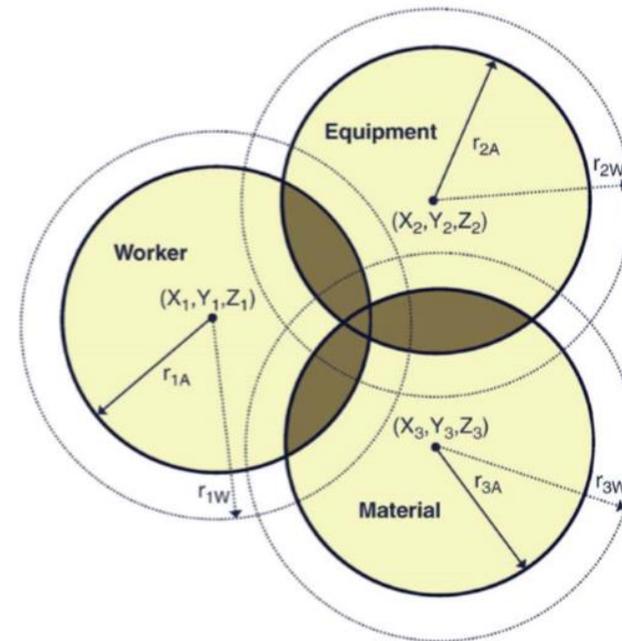

Warning radius and alert radius (Teizer, Allread et al. 2010)

Current Research Gap

WZIAT

Focus on intrusions of passing vehicles.

OR

Crash Detection Inside Work Zone

Focus on crashes between workers and equipment or construction materials.
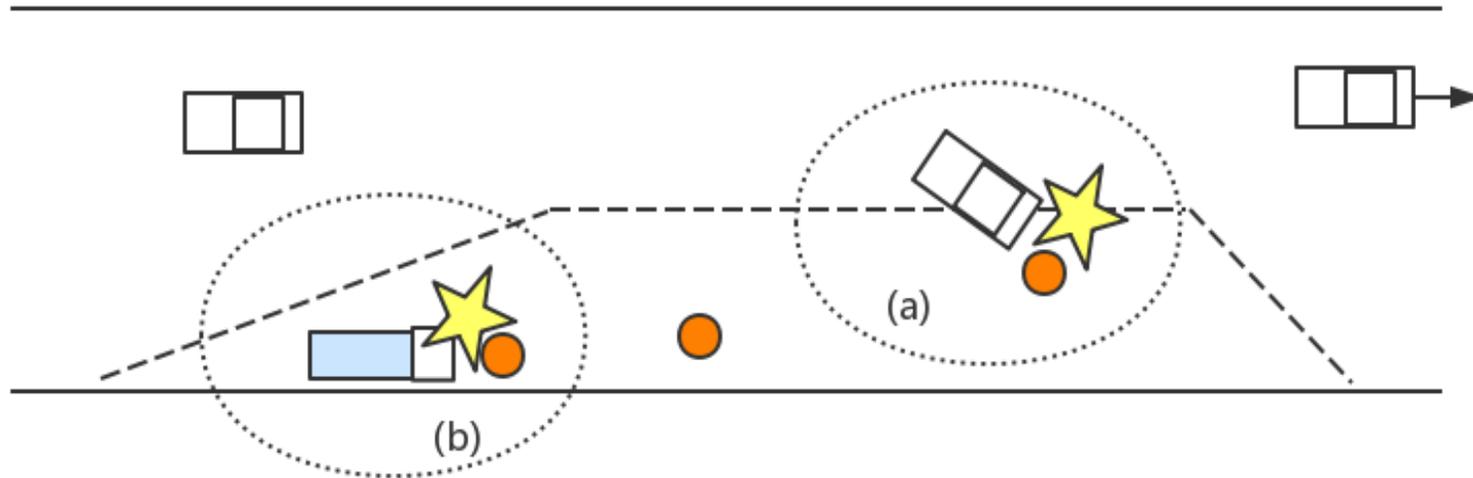
*(a) Collisions from outside the work zone; (b) Collisions from inside the work zone*

Research Scope

- Connect **inside** and **outside** of the work zone

- Receive **real-time locational data**

  - **Workers**

  - **Connected and automated vehicle (CAV)**

  - **Construction equipment**

- Detect **potential hazards**

- Provide **real-time messages and instructions**

- **Recognize activities** of workers.

- **Demonstration & Experiments**

Data Collection & Communication

UWB tags and anchors

Real-time communication
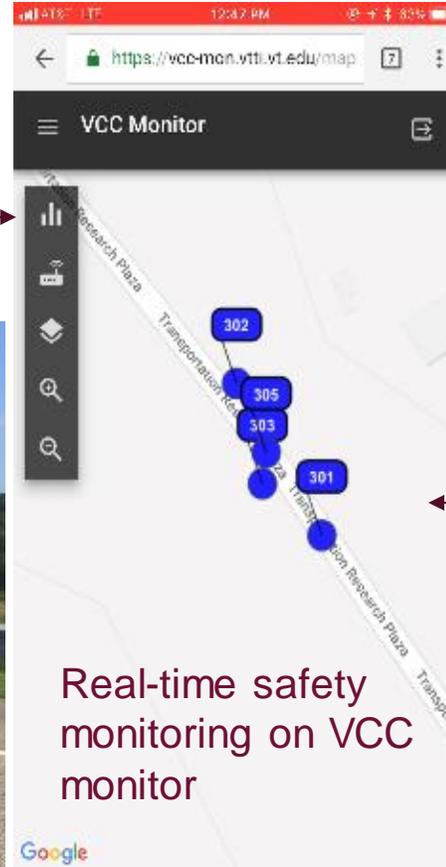
Real-time safety monitoring on VCC monitor

Data Collection & Communication

Work Zone
- CAVs
- Equipment
- Workers-on-foot
- WZ Border

UWB, OBU

Server

Location, Speed, Heading, Dimension

Algorithm

Message Commands

Message

VCC Monitor/App

- Calculate threat zones
- Recognize activity/movement pattern
- Predict Unsafe Proximities, Detect imminent threats
- Provide warning messages & instructions
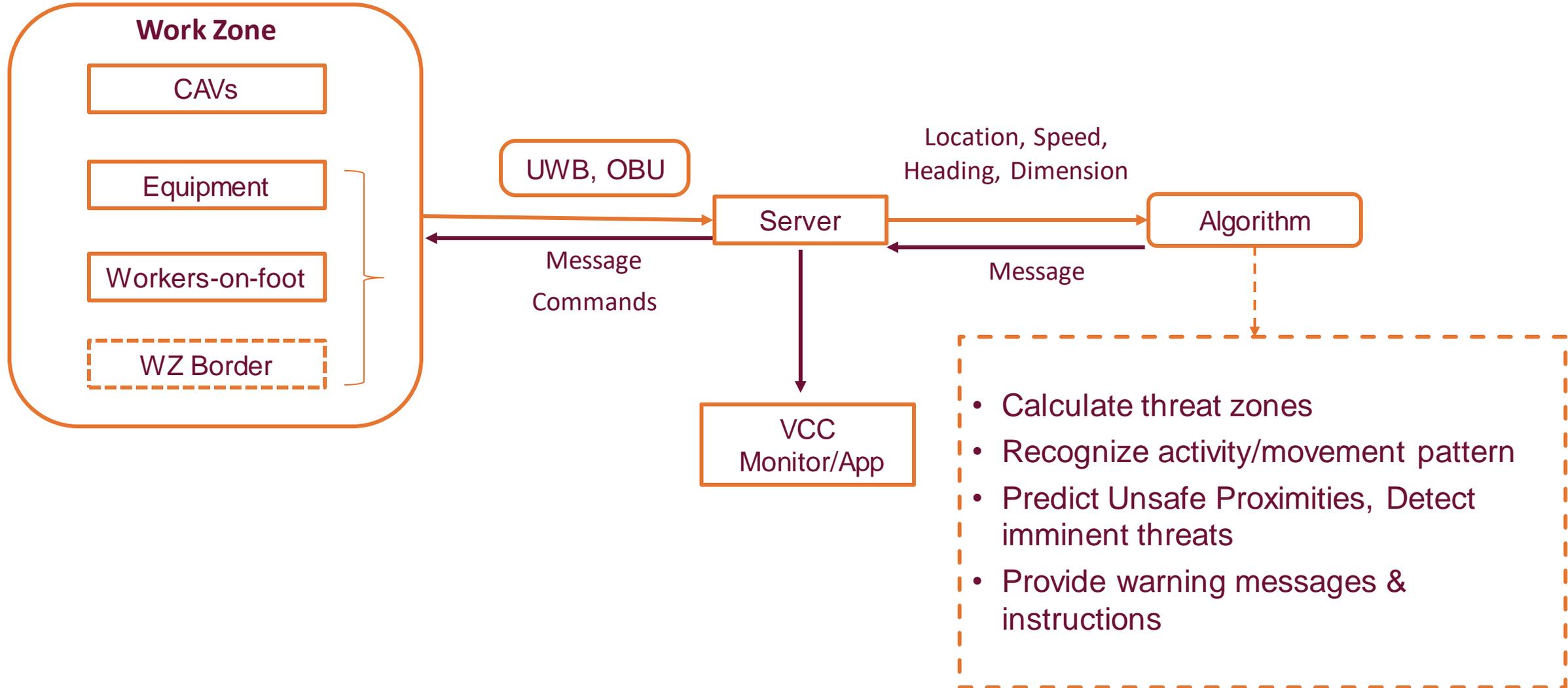
Algorithm Design- Workers-on-foot

- **General Threat Zone**

- **Distance to the work zone border (only consider workers-on-foot)**

- **Road Shape (Straight/Curve Section)**
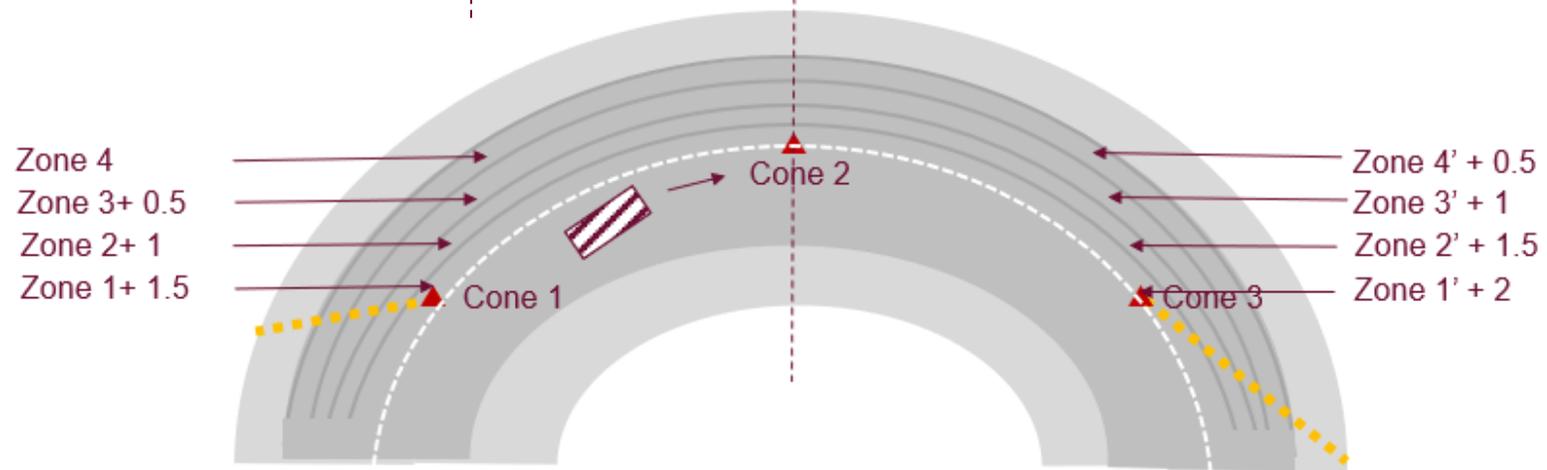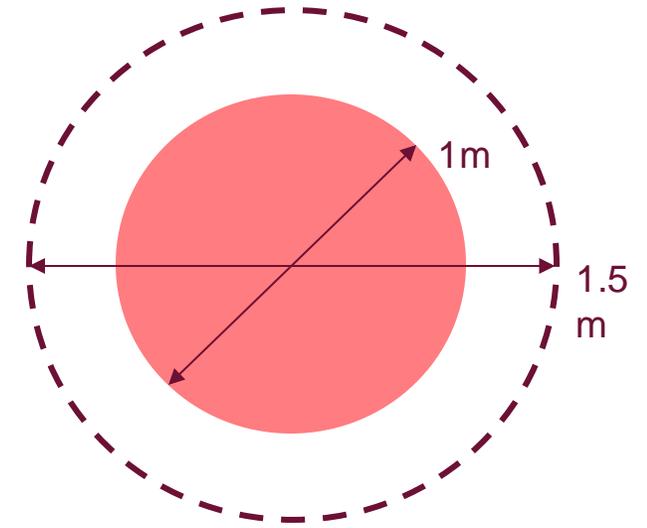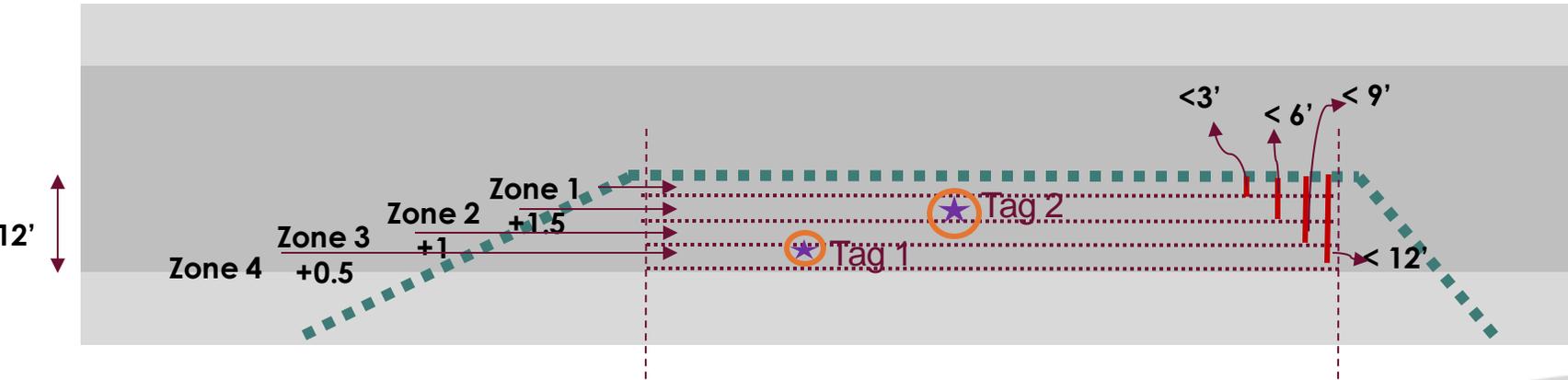
Threat Zone Design - Vehicle(CAV) & Equipment

- **General Threat Zone (Teizer 2015)**

- General alert zone distance: 1 m (Vehicle) & 1.5m (Equipment)

- Steer degree of CAV: 6 degree (Zhao et al. 2014)

- Driver reaction time (t_1): 2 seconds (Copradar 2017)

- Friction coefficient (u): 0.8 dry road (Chen et al. 2017)
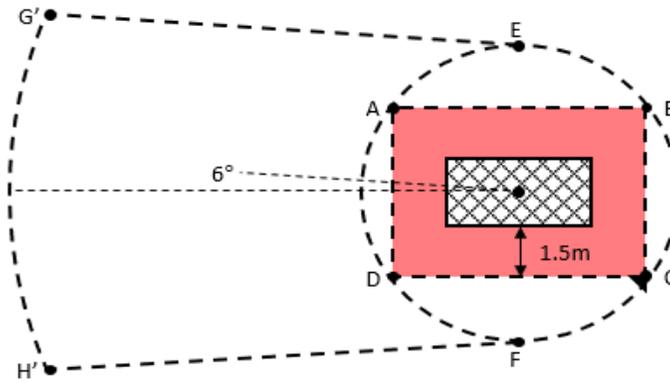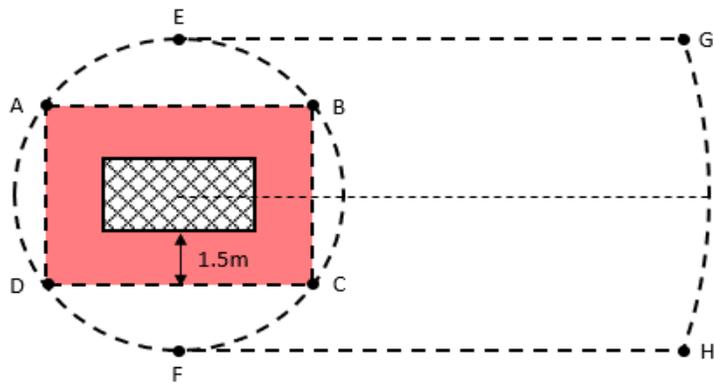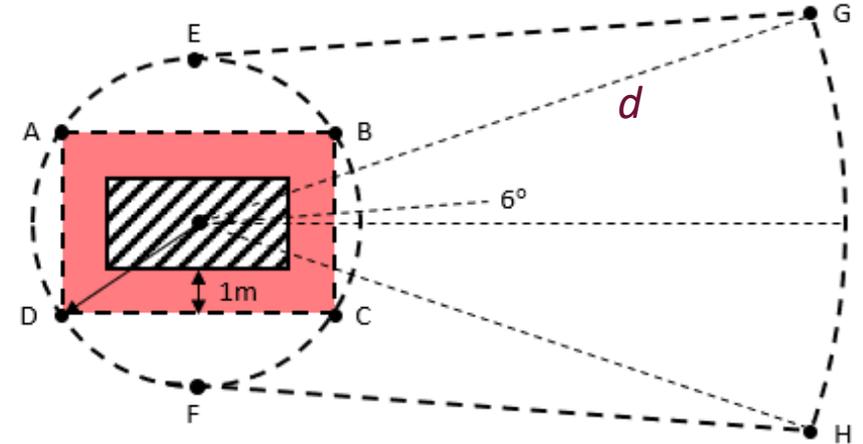
Alert zone: ABCD
Warning zone: ADFHGE
Warning distance: d

$$d = vt_1 + v^2/2a$$
$$a = ug$$

Database Design

ID	Worker Activity	Worker Speed(m/s)	Description/Charateristics
18	Dig		use shovel/tool, static, random position
3	Drill		static, use driller
4	Drive		use vehicle, see vehicle charateristics
6	Fill		Pothole filling, static, use shovel
15	Guide		can be edge or out of work zone, flag, guide truck
19	Install/Uninstall		install barricades, cones, and markers
17	Load/Unload		near back of truck, static, small range movement
27	Measure		measure, mark point, big range
2	Moving-Tool Handle		slow walking with roller, parallel to road
21	Mow		similar to trim, only for grass
16	Paint		1-3 workers, walk slow, with tool, not continous
25	Pour		
26	Repair		Other movements of fixing structure
11	Run	>1.79	
20	Saw		1 or 2 workers, with saw, no position specific
24	Spread		
12	Sweep		slow walking with broom, or picking items
23	Tamp		use tool (tamper), slow, specific area
13	Trim		slow walking on shoulder/edge, with trimmer
22	Turn		change direction
14	Walk	0.89-1.79	

Activity database

Proximity Detection & Visualization Diagram
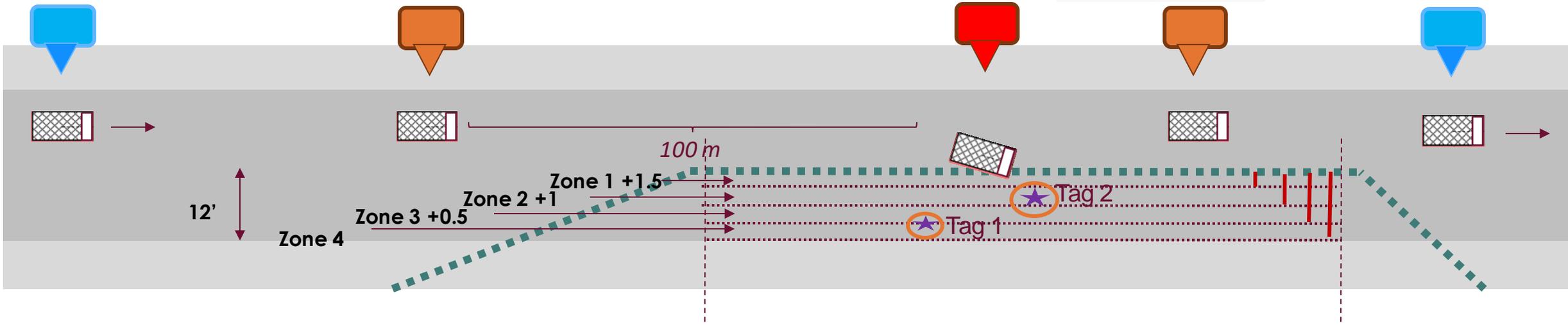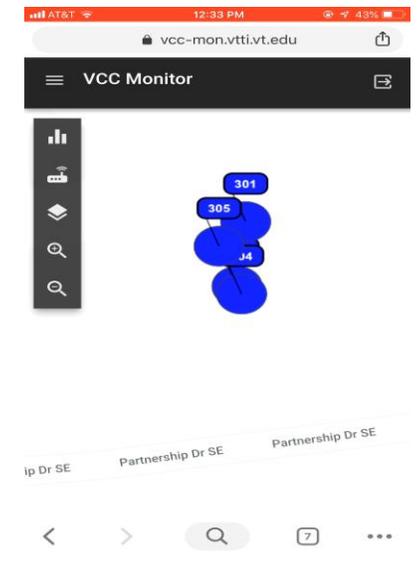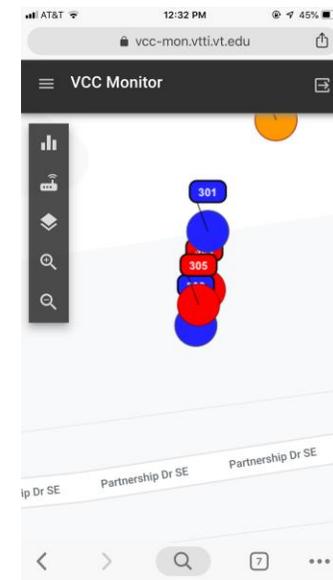
Activity Recognition

Activities Category:

	Category	Description
1	Jackhammering (3)	Utilizing hand-held equipment which required consistent or inconsistent static position, such as jackhammer, drill, etc.
2	Walking (16)	Normal walking or running of workers.
3	Rolling (10)	Utilizing hand-held equipment which required regular moving, such as small compactor, etc.
4	Guiding (14)	Workers may walk backward to guide dump truck or other heavy equipment to adjust their locations.
5	Random (6)	Random movement of workers, may include change of directions and other unpredictable activities.

Ensemble Bagged Trees

- Accuracy: 75.5%

- Confusion Matrix

Influencing factors identification:

- Average speed

- Static time

- Parallel/perpendicular to traffic

- Moving in/against traffic direction

Model 4.11 — Confusion Matrix (True class vs Predicted class)
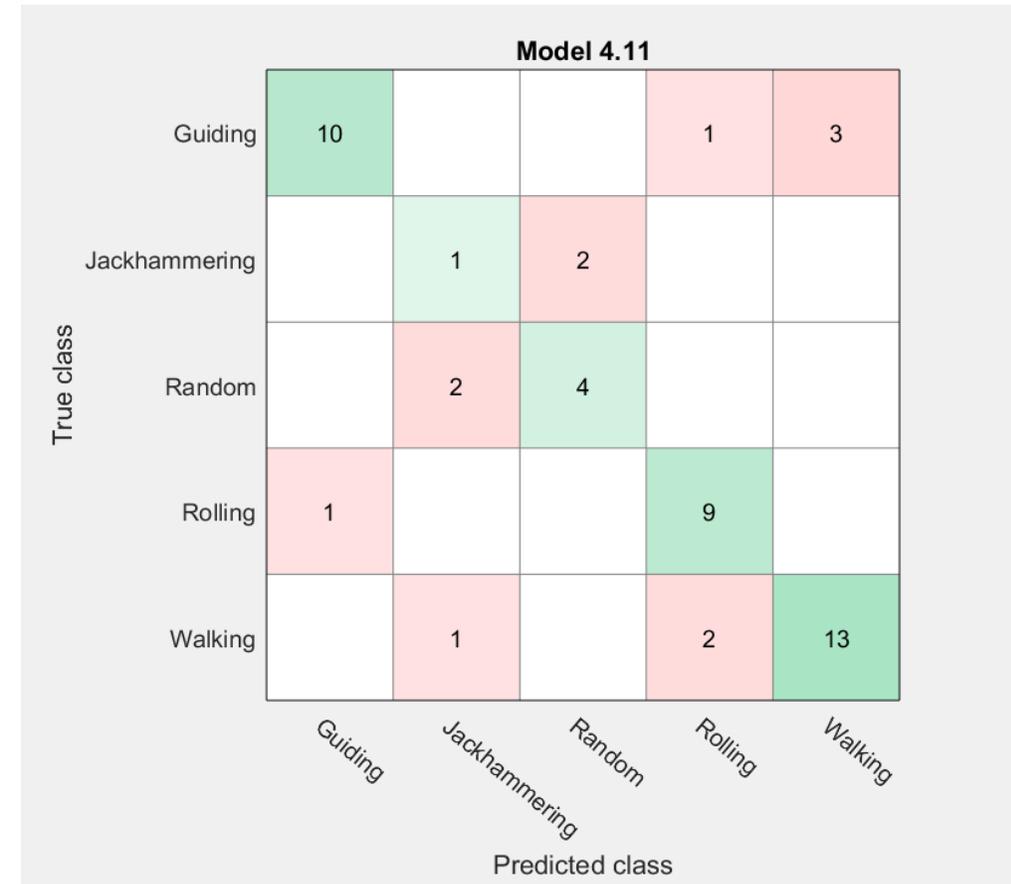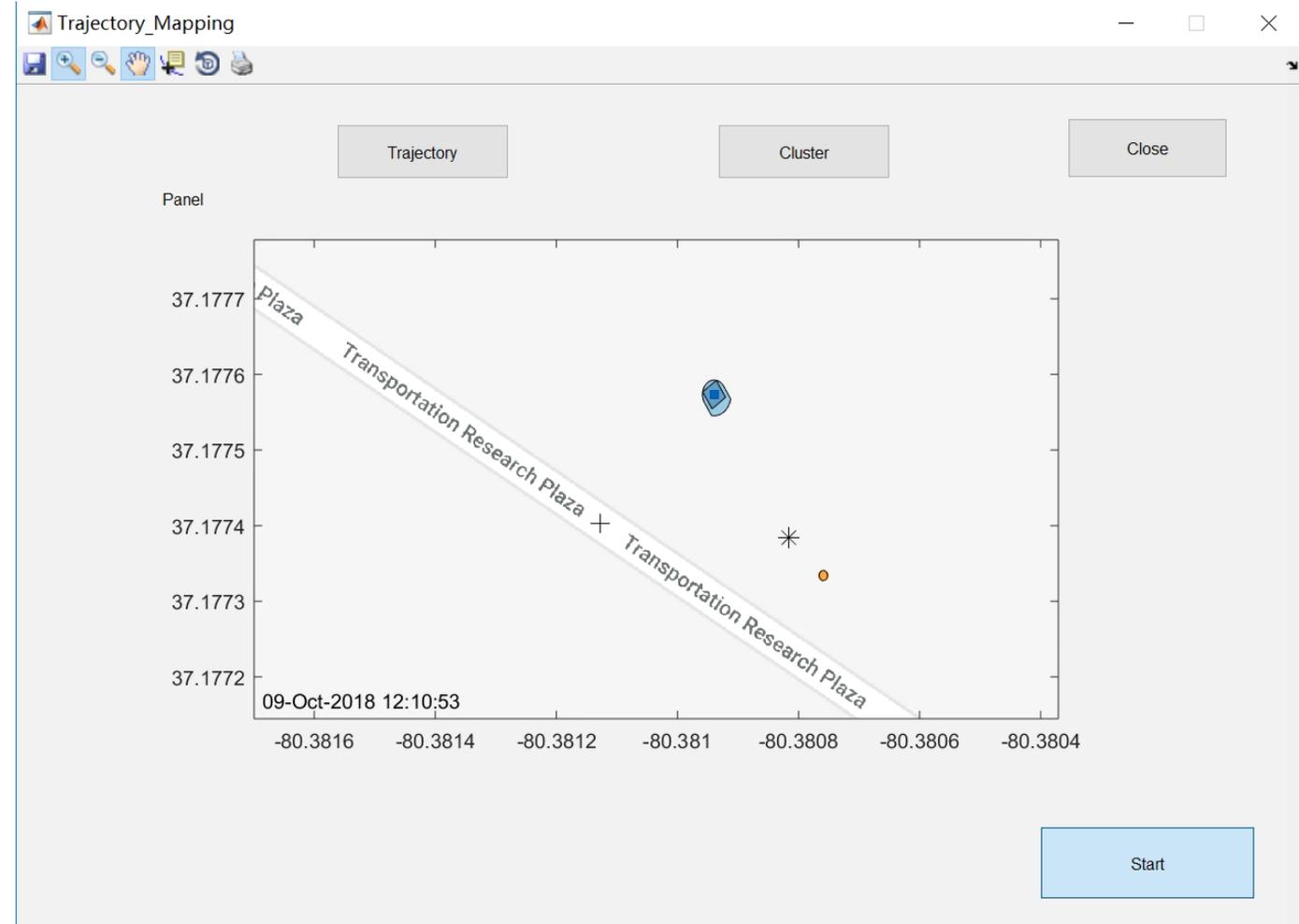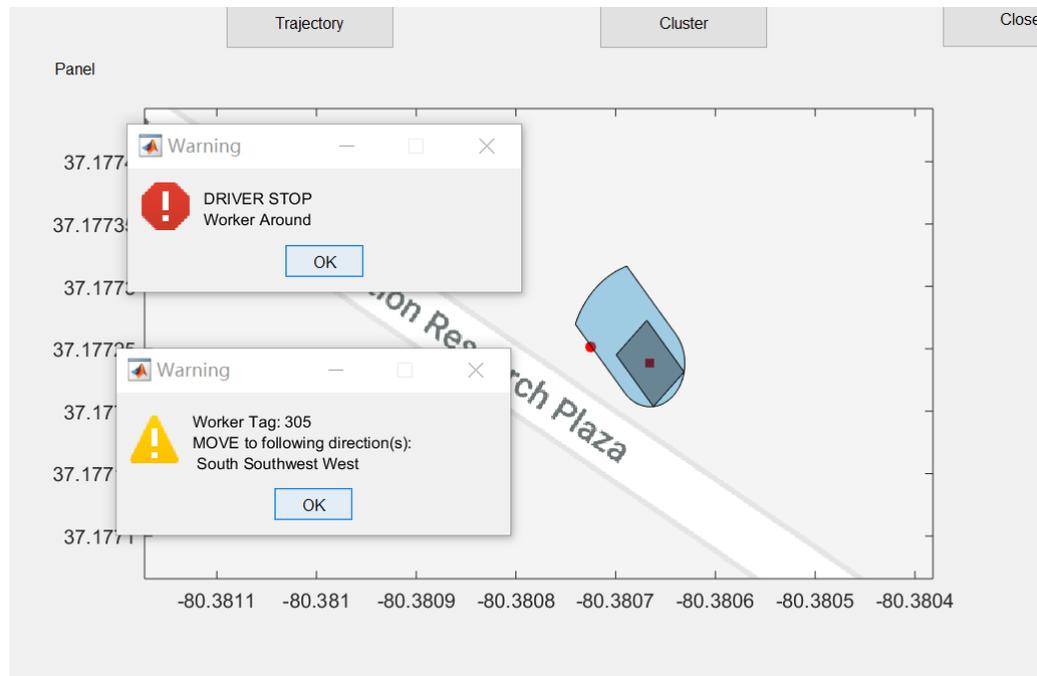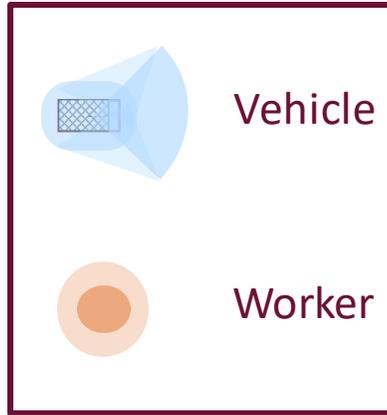
Demonstration

- Multiple work zone scenarios set up with workers on foot and equipment

- VCC Monitor will show the work zone entities in real-time
  - Blue = safe
  - Orange = proximity/workers in the area
  - Red = threat detected

- Safe-D application will show alerts received by CAV
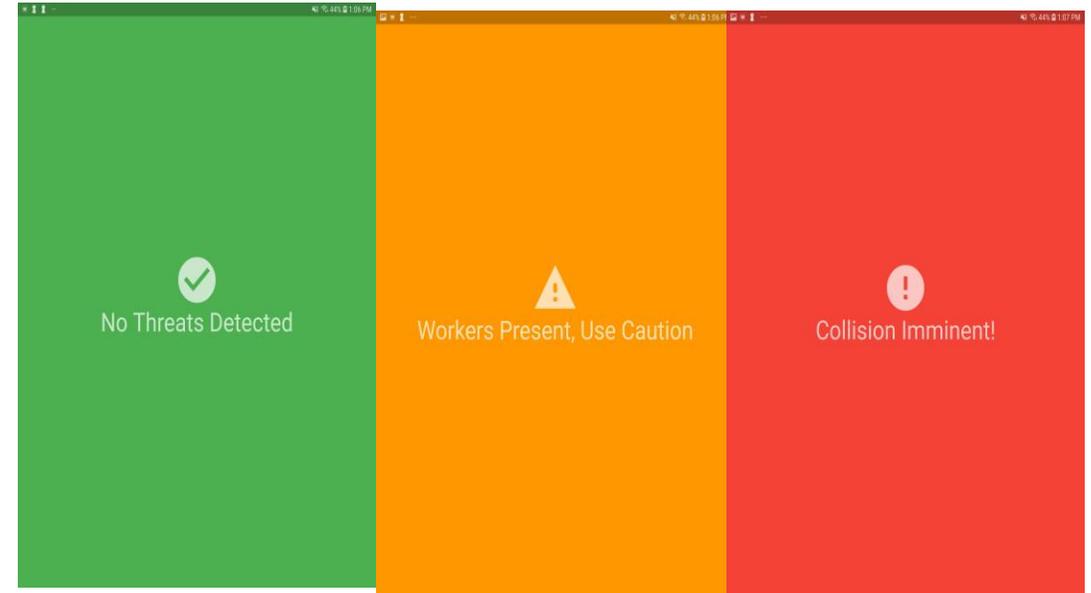
Demonstration

data:Received message: Threat,304,Worker,MOVE to following direction(s),   Northeast

data:Received message: Threat,305,Vehicle/Equipment,Worker,304,is in your way

data:Received message: Threat,304,Worker,MOVE to following direction(s),

data:Received message: Threat,305,Vehicle/Equipment,Worker,304,is in your way

data:Received message: Threat,304,Worker,MOVE to following direction(s), North   Southwest West Northwest

data:Received message: Threat,305,Vehicle/Equipment,Worker,304,is in your way

data:Received message: Threat,304,Worker,MOVE to following direction(s),   South Southwest West Northwest

data:Received message: Threat,305,Vehicle/Equipment,Worker,304,is in your way

data:Received message: Threat,304,Worker,MOVE to following direction(s), North   Southeast South Southwest West Northwest

data:Received message: Threat,305,Vehicle/Equipment,Worker,304,is in your way

data:Handshake complete. Listening for messages on the TCP socket. There are currently 1 active TCP socket connections.

data:Received message: Safe,304,Worker,Other actors are away

data:Received message: Safe,305,Driver,Other actors are away

data:Received message: Threat,304,Worker,MOVE to following direction(s),   East Southeast South Southwest West Northwest

data:Received message: Threat,305,Vehicle/Equipment,Worker,304,is in your way

data:Received message: Safe,304,Worker,Other actors are away

data:Received message: Safe,305,Driver,Other actors are away

data:Handshake complete. Listening for messages on the TCP socket. There are currently 1 active TCP socket connections.

data:Handshake complete. Listening for messages on the TCP socket. There are currently 1 active TCP socket connections.

Research Summary
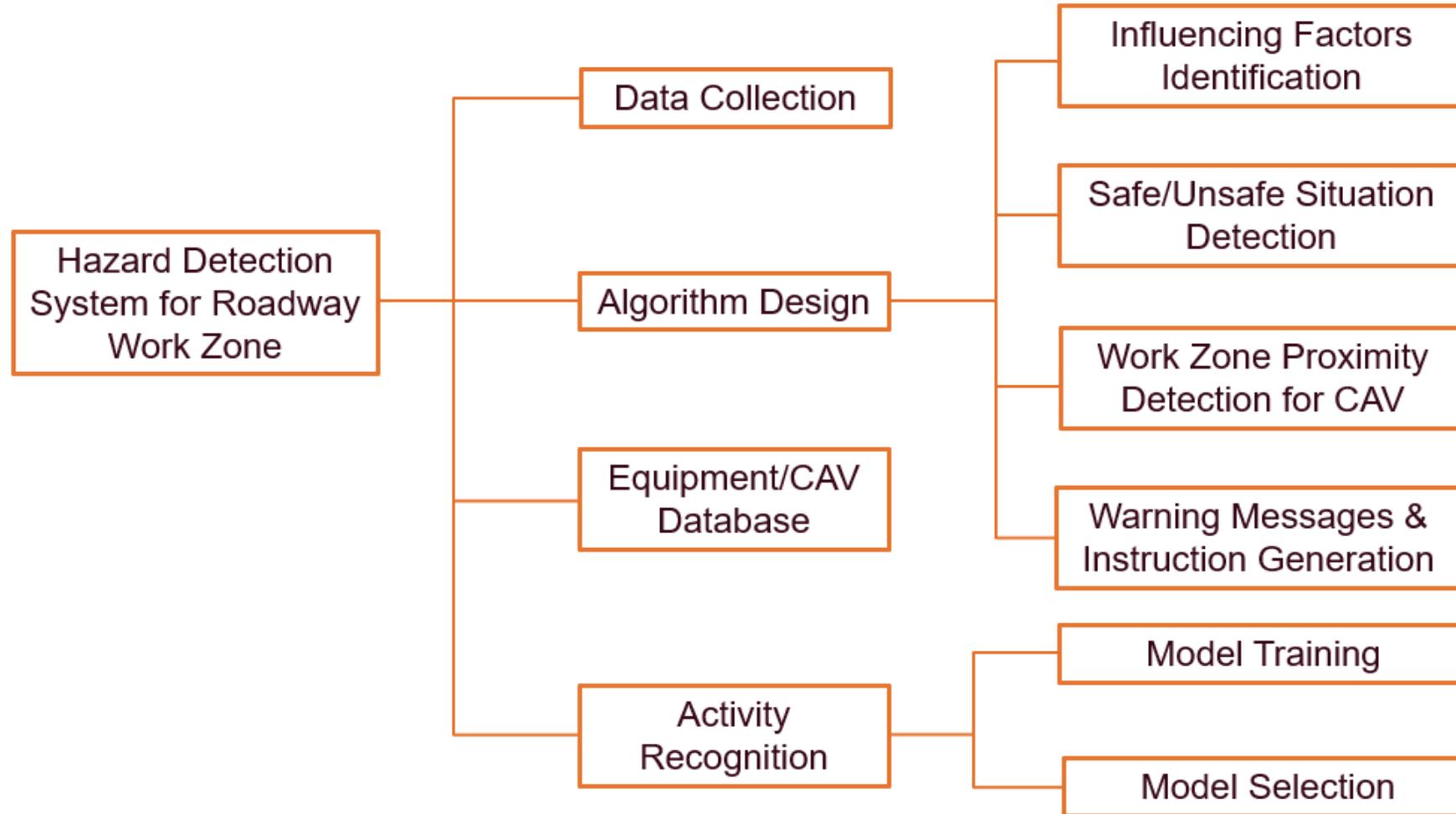
Research Significance

- Provide a **holistic, efficient, convenient** hazard detection and warning system.

- **Enhance safety level** of construction sites.

- Help inspectors or managers in **monitoring the real-time work zone remotely**.

Future

- Collect more activity samples from experiments

- Develop methods to **alert workers and equipment operators**

- Develop **new safety garment** with hazard detection application

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THANK YOU
&
QUESTIONS

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