



IV22

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Effects of Augmented-Reality-Based Assisting Interfaces on Drivers' Object-wise Situational Awareness in Highly Autonomous Vehicles

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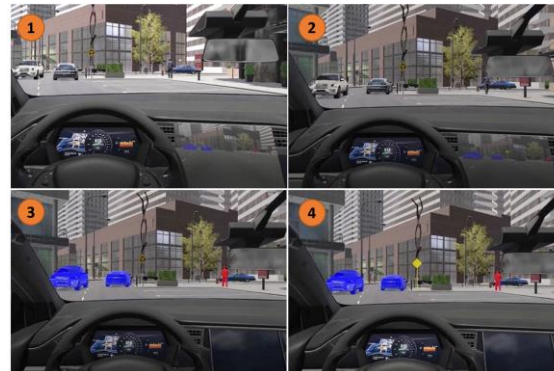
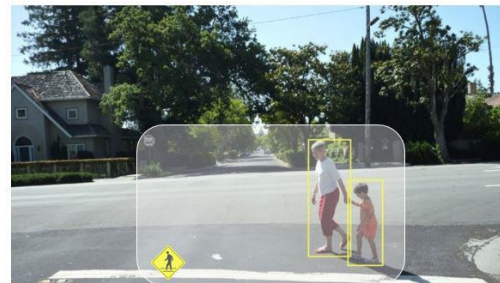
Work Done during Internship at Honda Research Institute USA

Background

- Fully-automated vehicles are not yet well-developed
- Necessary to maintain drivers' situation awareness (SA) for semi-autonomous vehicles
 - Prepare them for sudden maneuvers and possible take-overs
 - Form basis of trust
- However, SA reduce as drivers are becoming out of the loop

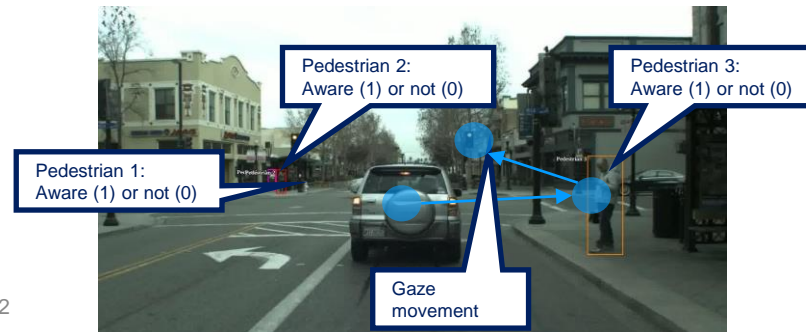
Related Work

- Possible solution to provide situational information: user interface based on head-up displays (HUDs)
 - Example: highlighting detected objects using bounding boxes or semantic segmentation
- Limitations in existing study
 - Specifically designed scenarios
 - Aimed for long term effects of highlighting on SA
 - All objects are always/never highlighted throughout the drive
- Our contributions
 - Standardized scenarios in intersections
 - Novel protocol to examine short term effects on SA



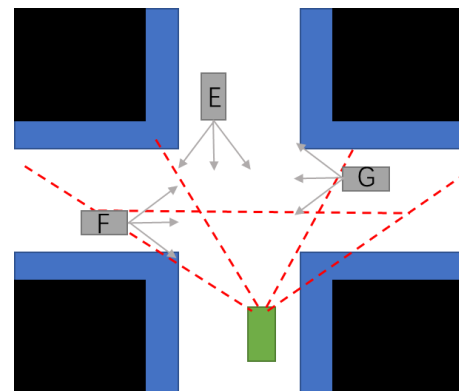
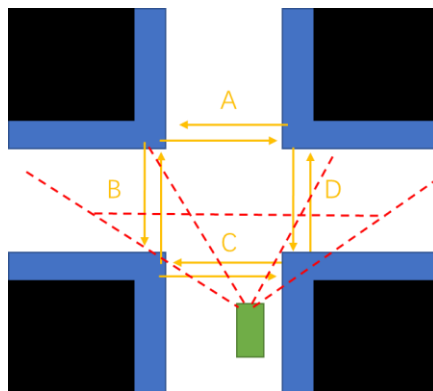
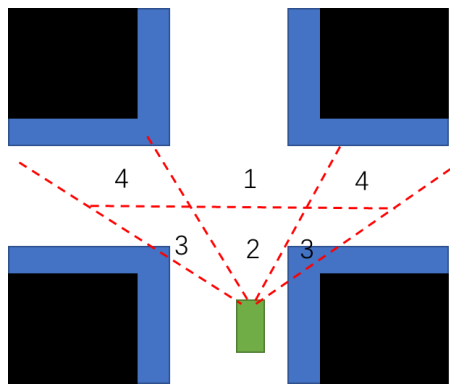
User Study Basics

- Implemented in the UE4-based driving simulator
- Highlight object using bounding boxes
- Tobii-glasses to collect gaze data
- Pause to get SA response (SAGAT)
- Effects of highlighting on object SA :
 - Traffic density (low/high)
 - Object positions in the intersection
 - Object types (car/pedestrian)



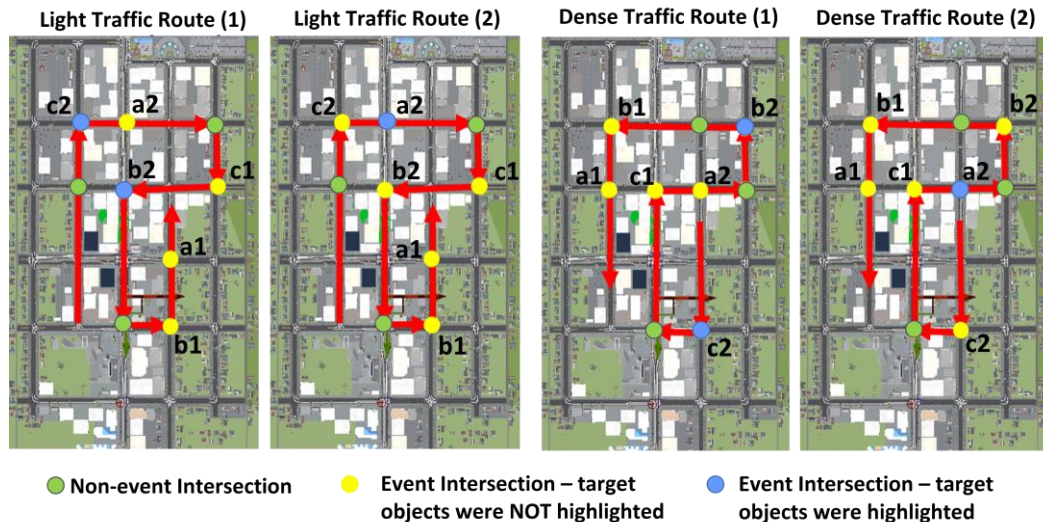
Object Position Discretization

- Discretize object positions based on the visual saliency
 - 1: top center; 2: bottom center; 3: bottom left and bottom right; 4: top left and top right
- Pedestrian movements:
 - A: area 1; B: areas 3 and 4; C: moving in areas 2 and 3; D: moving in areas 1 and 3
- Similar discretization can be applied to car movements



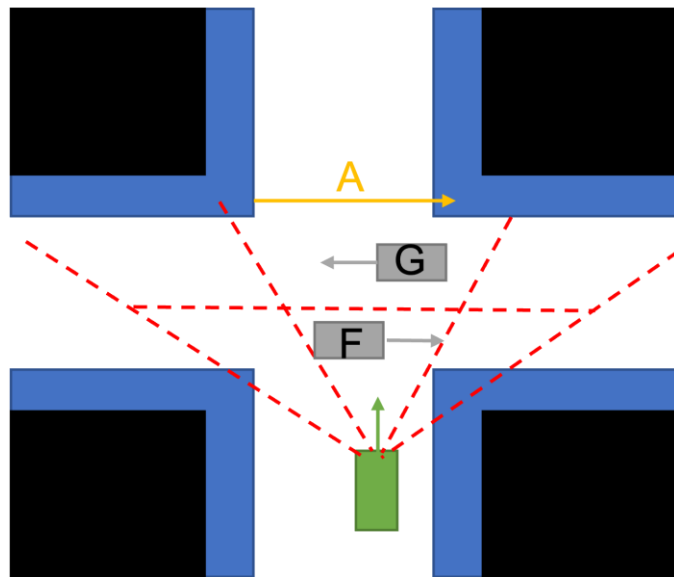
Study Design

- Traffic Density for intersections
 - Light (5 objects)
 - Dense (10 objects)
- Each drives contain 3 pairs of intersections
 - Forward: a1, a2
 - Left: b1, b2
 - Right: c1, c2
 - Similar events in one pair
 - SAGAT timing is different
 - a1, b1, c1: early (at t)
 - a2, b2, c2: late (at t+1)
 - Goal: quantify the effects of highlighting during the delayed period



Forward Scenarios: a1 and a2

- Ego car going **straight** is waiting by the stop sign
- Target objects: pedestrians A; cars G and F
- SAGAT timing:
 - A at 1, G at 1, F at 2



Forward Scenario Demo

- a1: early SAGAT, top center pedestrian and center cars unhighlighted

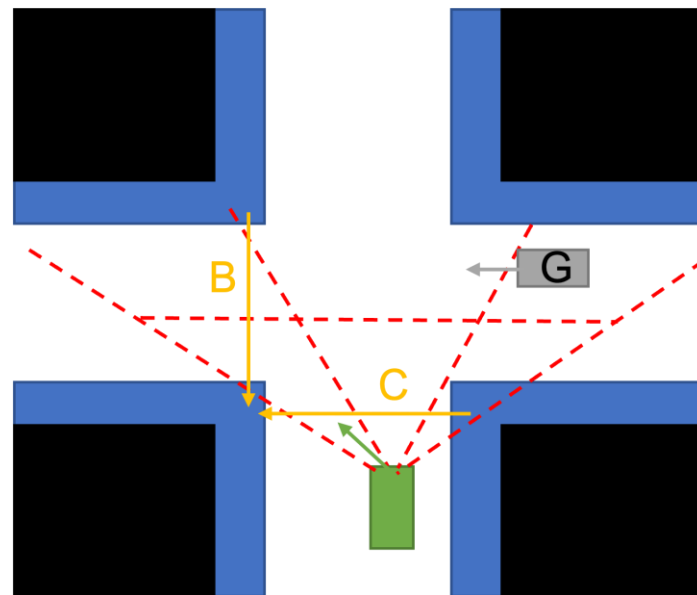


- a2: late SAGAT, top center pedestrian and center cars highlighted



Left Scenarios: b1 and b2

- Ego car going **left** is waiting by the stop sign
- Target objects: pedestrians B, C, car G
- SAGAT timing:
 - B at 4 (left), C at 2, G at 4 (right)



Left Scenario Demo

- b1: early SAGAT, top left pedestrian, bottom center pedestrian and top right car unhighlighted

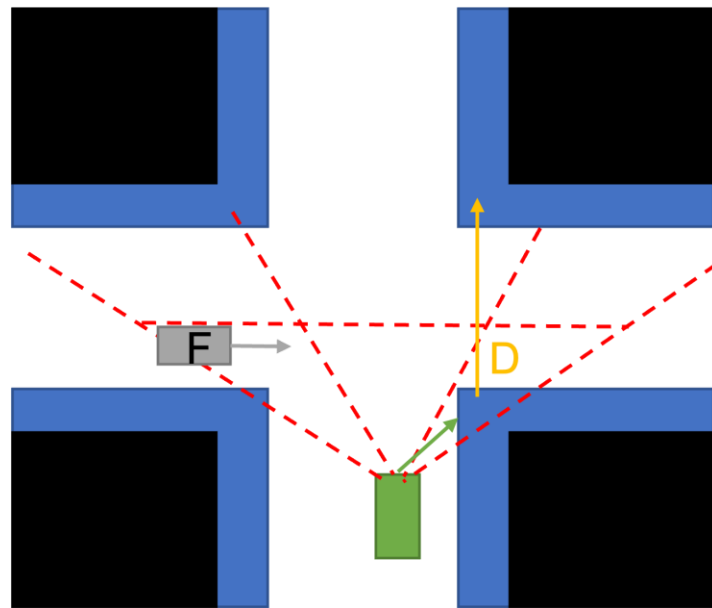


- b2: late SAGAT, top left pedestrian, bottom center pedestrian and top right car highlighted



Right Scenarios: c1 and c2

- Ego car going **right** is waiting by the stop sign
- Targets: ped D, cars F
- SAGAT timing:
 - D at 3 (right), F at 3 (left)



Right Scenario Demo

- c1: early SAGAT, bottom right pedestrian and bottom left car unhighlighted



- c2: late SAGAT, bottom right pedestrian and bottom left car highlighted



Data collection and annotation

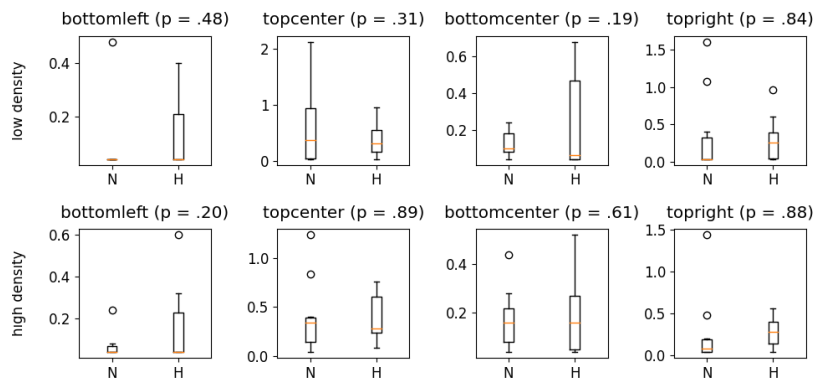
- 20 participants, each experiences 2 drives with different density
 - Group 1: LT1 and DT2
 - Group 2: DT2 and LT1
 - Group 3: LT2 and DT1
 - Group 4: DT1 and LT2
- Collect SA response on objects (threshold: 50)
- Fixations
 - Tobii glasses for eye movements
 - Annotate the target object locations using vatic
 - Criteria:
 - minimum gaze distance 4.1 degrees
 - minimum fixation dwell time 120ms



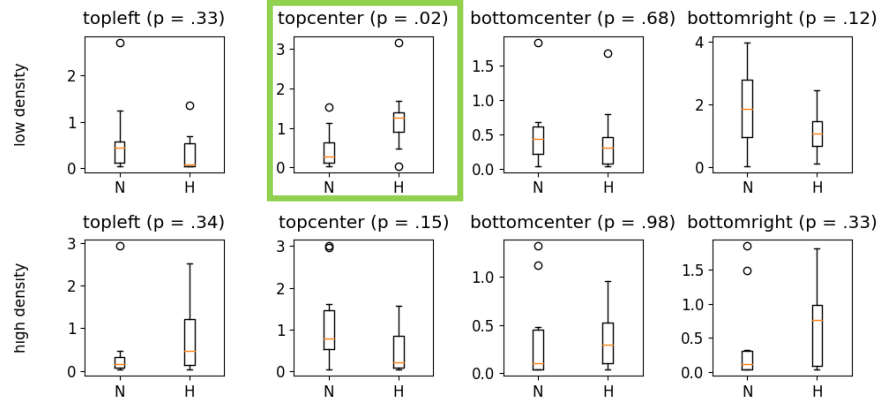
Fixation time

- Top center pedestrians get more fixation when highlighted for **light** traffic

Fixation on Cars

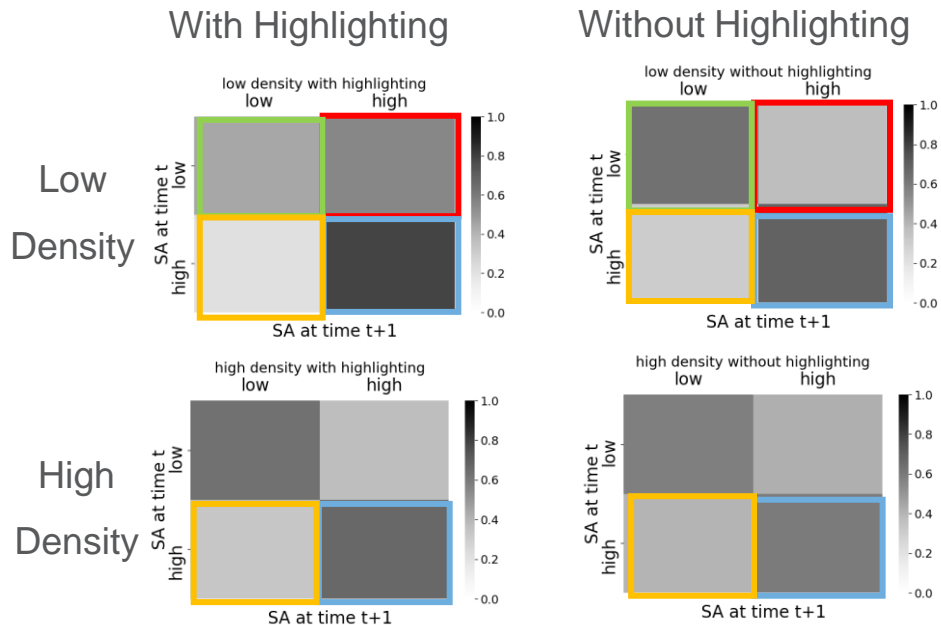


Fixation on Pedestrian



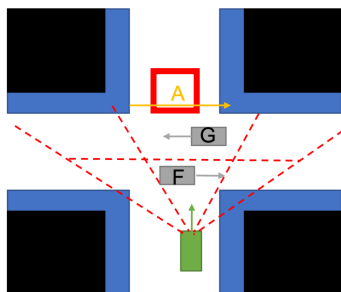
SA Transition Matrix across objects

- SA change as a result of highlighting
- Darker color means more proportion
- With highlighting vs without
 - More improve their SA **at light traffic** (top right: low to high)
 - More keep the correct answers (bottom right: high to high)
 - Less stick to low SA **at light traffic** (top left: low to low)
 - Less switch to low SA (bottom left: high to low)

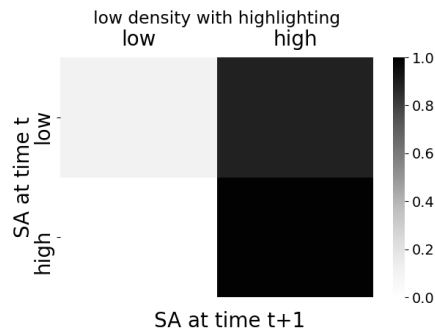


SA Transition Matrix (Object-wise)

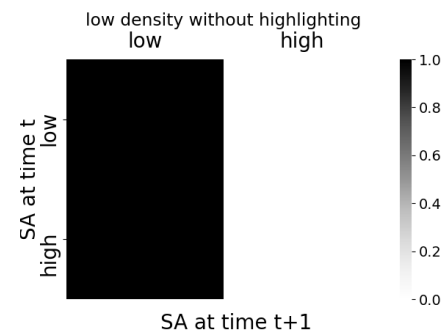
- Object SA improved with highlighting
 - Top center pedestrian at light traffic**



With Highlighting

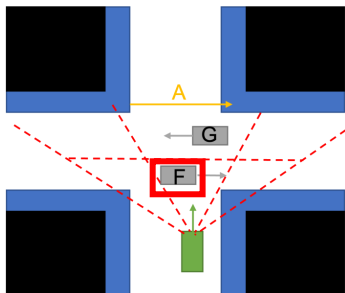


Without Highlighting

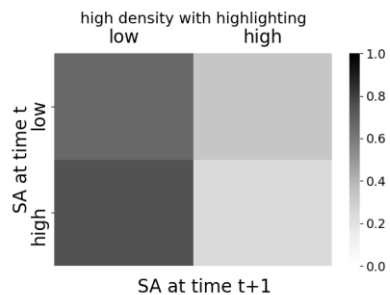


SA Transition Matrix (Object-wise)

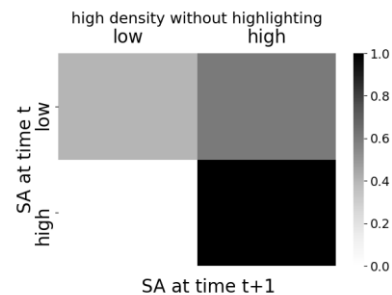
- Object SA deteriorated with highlighting
 - Bottom center car at heavy traffic**



With Highlighting

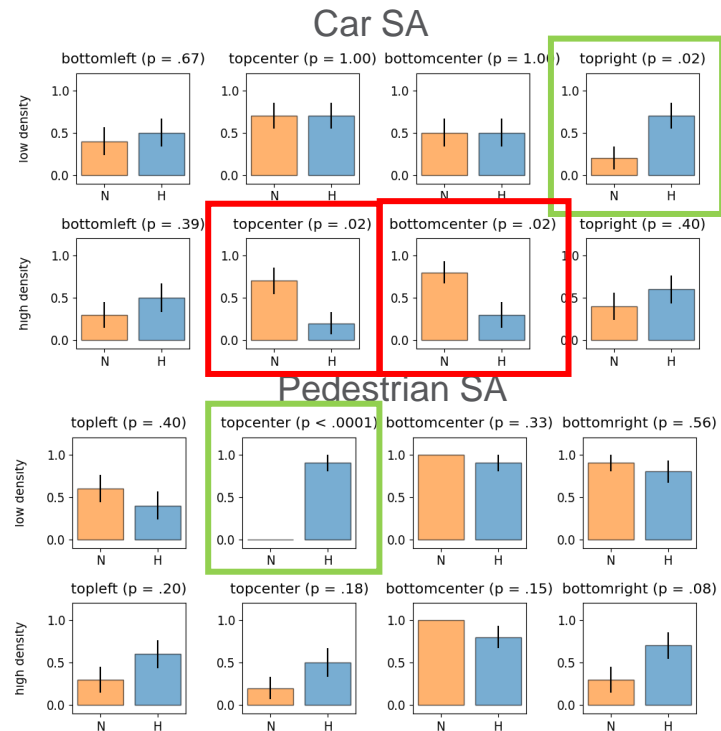


Without Highlighting



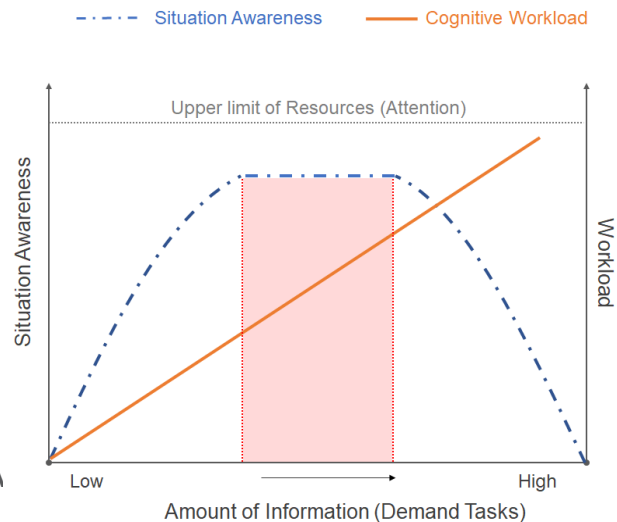
SA response accuracy

- Accuracy of SAGAT response on target objects in delayed intersections (a2, b2, c2)
- Highlighting increases SA accuracy significantly
 - At **light** traffic
 - **Top center pedestrian**
 - **Top right car**
- Highlighting decreases SA accuracy significantly
 - At **high** traffic
 - **Bottom center car**
 - **Top center car**



Conclusions

- Take-away: highlighting via HUD has mixed SA effects
 - Positive impact on object SA when
 - light traffic
 - low visual saliency for objects
 - Negatively affects object SA when
 - dense traffic
 - the object is salient even without highlighting
- Future work
 - An adaptive user interface that can highlight important objects selectively to maintaining low workload and high SA



Thank You
