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
Effects of Human-Machine Interface on Driver’s Situational Awareness

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**
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)

With Highlighting

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<th>SA at t+1</th>
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Without Highlighting

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SA Transition Matrix (Object-wise)

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

With Highlighting

Without Highlighting

Effects of Human-Machine Interface on Driver’s Situational Awareness

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SA Transition Matrix (Object-wise)

• Object SA deteriorated with highlighting
• Bottom center car at heavy traffic
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