Introducing “LISA”

LISA: Laboratory for Intelligent and Safe Automobiles

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Int. Workshop on
Progress and Future Directions of
Adaptive Driver Assistance Research

National Highway Traffic Safety Administration
Washington, DC
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Presentation Outline

Research Scope

LISA Overview: Video Clip

Research Samples:
  • Real-time Occupant Posture Analysis
    • Driver View Estimation
    • Driver Affect-State Analysis
    • Vehicle Surround Capture
    • Driver Behavior Analysis (Lane Change)
    • Multitasking and Attention

Concluding Remarks
Research Scope

How to enhance Safe and “Efficient” Driving?

Multidisciplinary Focus on:

• Development of Complete Driving Context Capture System
• Robust Computational Algorithms for Context/Intent Analysis
• Detailed Behavioral Analysis of Driver and Driving Tasks
• Mental Models for Attention and Multitasking
• Multimodal Interfaces for Driver Attention Management

Vision Based “Smart Airbag” system

Scene sensing

- Single perspective
- Thermal camera
- Stereo system
- Multicamera system

Feature selection and analysis

- Region occupancy analysis
- Simplified body model
- Detailed body model

Posture categories

- Must not deploy
- Depowered deploy
- Must deploy
Stereo, Voxel, & Thermal IR Video Streams Capture in LISA-P


Real-Time Head Tracking

### Stereo vs. Thermal IR

<table>
<thead>
<tr>
<th>Occupant Task</th>
<th>Male 1, 5’8”</th>
<th>Female 1, 5’8”</th>
<th>Female 2, 5’11”</th>
<th>All Occupants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stereo</td>
<td>LWRStereo</td>
<td>LWRStereo</td>
<td>LWRStereo</td>
</tr>
<tr>
<td>Sit Normal</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
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<tr>
<td>Lean Halfway</td>
<td>100.0%</td>
<td>73.0%</td>
<td>92.0%</td>
<td>82.0%</td>
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<tr>
<td>Lean Forward</td>
<td>76.6%</td>
<td>8.4%</td>
<td>8.4%</td>
<td>8.4%</td>
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<tr>
<td>Return to Normal 1</td>
<td>100.0%</td>
<td>89.0%</td>
<td>89.0%</td>
<td>89.0%</td>
</tr>
<tr>
<td>Lean Back</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Return to Normal 2</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Lean Left</td>
<td>100.0%</td>
<td>86.0%</td>
<td>86.0%</td>
<td>86.0%</td>
</tr>
<tr>
<td>Return to Normal 3</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Face Motion Test Totals (Number of Frames)</td>
<td>97.3%</td>
<td>96.2%</td>
<td>96.2%</td>
<td>96.5%</td>
</tr>
<tr>
<td>Move Hands about cabin</td>
<td>75.3%</td>
<td>100.0%</td>
<td>97.4%</td>
<td>97.0%</td>
</tr>
<tr>
<td>Open the glovebox</td>
<td>100.0%</td>
<td>100.0%</td>
<td>95.5%</td>
<td>74.3%</td>
</tr>
<tr>
<td>Pick up or face &amp; stretch</td>
<td>81.7%</td>
<td>100.0%</td>
<td>85.2%</td>
<td>87.8%</td>
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<tr>
<td>Adjust seat belt</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
<td>99.4%</td>
</tr>
<tr>
<td>Pass hat to lap</td>
<td>100.0%</td>
<td>100.0%</td>
<td>97.2%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Put hat on head</td>
<td>98.0%</td>
<td>98.3%</td>
<td>98.0%</td>
<td>98.0%</td>
</tr>
<tr>
<td>Move with hat</td>
<td>98.8%</td>
<td>97.0%</td>
<td>68.1%</td>
<td>62.4%</td>
</tr>
<tr>
<td>Remove hat</td>
<td>100.0%</td>
<td>100.0%</td>
<td>62.1%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Eat on dashboard</td>
<td>100.0%</td>
<td>96.0%</td>
<td>74.6%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Hand Motion &amp; Object Test Totals (Number of Frames)</td>
<td>93.4%</td>
<td>97.4%</td>
<td>90.6%</td>
<td>88.5%</td>
</tr>
<tr>
<td>Tie Motion Test (Number of Frames)</td>
<td>100.0%</td>
<td>100.0%</td>
<td>95.4%</td>
<td>95.4%</td>
</tr>
<tr>
<td>All Test Totals</td>
<td>95.4%</td>
<td>98.2%</td>
<td>97.9%</td>
<td>94.4%</td>
</tr>
</tbody>
</table>

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**Tracking Body Parts and Objects**


Driver Head-Pose and View Estimation with a single Omni-video Stream

Challenges:
- Drastic illumination changes, both on brightness and color.
- High frame rate (30fps) to capture detailed dynamics.


Results: Occluded Face

Driver Seat  Head Detection  Head Tracking  Driver’s Face

Estimated Driver’s View

Head and Face Orientation Estimation


Driver Affect Analysis

Initialization → Feature Tracking

Bayesian Estimation and Affect Classification

Driver Affect

• Face Landmarks tracked in real-time
• Thin-plate spline warping separates rigid head motion from non-rigid face affect motion
• Warping parameter is classified into face affect or expressions

J. McCall and M. M. Trivedi, "Pose Invariant Affect Analysis using Thin-Plate Splines" Proceedings of International Conference on Pattern Recognition 2004

Full Surround Capture: an Integrated Approach

LISA-Q: A Novel Test-bed


LISA-Q Test Bed

- Capable of extracting multiple modalities of sensor information for recording and/or processing
  - CAN Bus
    - Steering angle, pedal positions, vehicle speed, etc.
    - LASER RADAR distance to lead vehicle
  - 8 full frame video streams
    - Omnidirection cameras for 360 surround
    - Forward and rear facing rectilinear cameras
    - Rectilinear camera facing driver
    - Near-IR camera facing feet and pedals
    - Rectilinear camera mounted on headband for driver’s view
  - GPS data
  - PC in trunk for data collection/processing


Sensor Fusion for Context Capture
Ethnographic analysis

- Study natural situations of activity
- Confront heterogeneous data:
  - environment,
  - Driver’s behavior
  - Driver’s verbalization during action and after
  - Questionnaire,…
- Determine what is going on with the people
- Characterize meaning and expectation

Behavioral patterns

- Automatic detection from system/movies
  - Cheaper in time and effort
  - Allows analysis and comparison on large scale
  - Open possibilities of detection by the system
- Give traces of driver’s activity/context
  - Lane position => trajectory management
  - Head movement => control on traffic and road
  - Foot activity on gas/break => Speed management
- Find patterns to:
  - test similarities/differences between drivers/situation
  - predict the driver’s situation?
Behavioral Data Collection

DATA FLOW SCHEMATIC:

- Cameras
- Dv bridges
- Other data inputs

- OMNICam
- FOOTCam
- REARcam
- FACEcam
- FRONTCam

- Quad

- Headrest 1
- Headrest 2
- Headphones

Extracted from the movies
From the car system

- Lateral position
- Speech
- Head movement
- Foot activity
- Gas/brake
- Steering angle
- ACC
- Distance of target car

GPS location of the timeline

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Head and Gaze Movement Categories

- Look forward
- Look up (rear mirror)
- Look passenger
- Small look right (mirror)
- Medium look right (window)
- Big look right (over shoulder)
- Very big look right (maneuver)
- Big look left (over shoulder)
- Very big left (maneuver)
- Small Down (speed)

Wheel and hand position

- Ethnographic categories of hand position
- System measure of steering angle
- Problematic for Automatic Coding: HANDS VISIBLE

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Foot position

Ethnographic categories of foot position

- On the gas
- Hovering the gas
- Feet free
- On the brake
- Hovering the brake
- In the brake

Speech detection

Automatic detection of moment of speech

Use of speech detection for transcription and coding
Lane Changing 1

Says "15"

look right over shoulder

checks directions

Lane Changing 1

Freeway Sign for 15

car on right lane

On exit lane to 15

No more cars, signs for an exit

Looking to the side

"15" "Is this the 15?"

"Yeah"

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Getting space to think

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**Observations: steps of LC**

1. **Awareness of instability, caused by:**
   - LC1: Road, do not want to miss exit
   - LC2: Traffic, passing a truck
   - Change in preparation state: an intent is formed
     - LC1: During sequence,
     - LC2: Before sequence, when get blocked by truck

2. **Physical preparation: get ready for action**
   - placing hands
   - checking conditions (spot in lane)
   - changing speed to get the spot (in LC2 only)

3. **Execution:**
   - Checking if no car coming
   - Acceleration
   - Stabilization of the trajectory / checking car in new lane

**Concluding Remarks**

- HC-IDSS brings disciplines closer
- HC-IDSS will continue to challenging research community
- Current Efforts are focused on
  - Automatic Context Extraction
  - Intent Analysis
  - Multimodal (Audio, Visual, Haptic) Interfaces
  - Integrated System Evaluation

*Thanks!!*

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