Big Data Requires Collaboration
What Toyota is doing at our Collaborative Safety Research Center

Ed Mantey
Vice President, Toyota Technical Center
Seattle, WA
October 18, 2013
PacTrans Conference Theme of

- Data Collection
- Creating support tools
- Data Sharing

This is what CSRC is about!
1. CSRC Background
2. Research Projects
3. Big Data in Naturalistic Driving Studies
Announced January 2011

- Work with leading NA universities, hospitals, federal agencies...
- Benefit entire industry
- Estimate $50M over 5 years
- Advance Automotive Safety Research in NA – Share Globally

Collaborative Approach

Industry / Society

Proprietary / Internal

Open / External

Toyota Unique
Background

CSRC Three Pillars
1. Collaborative Research
2. Crash Data Analysis
3. Outreach – Actively Share

Research Focus
- Active Safety
- Driver Distraction
- At-Risk Populations
  - Children
  - Newly licensed teens
  - Seniors
  - Pedestrians
Pillar 1: Research Focus – Pre / Post Crash

16 Projects

10 Projects
Examples of Research

1) Biomechanics – Human Modeling

2) Post Crash
Examples of Research

3) Active Safety

4) Human Factors
Research Partners – Contracts (not grants)
Pillar 1: Research – 16 Partners, 26 Projects

Dr. Linda Boyle

College of Engineering
University of Washington

CSRC Collaborative Safety Research Center
TOYOTA
## Research Focus – Data Creation

### Biomechanics / Human Body Modeling Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Partner</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child and Elderly Female FE Model</td>
<td>Wayne State</td>
<td>10YO child &amp; senior female human body models</td>
</tr>
<tr>
<td>THUMS Simulation of Real World Crashes</td>
<td>Wake Forest</td>
<td>Published crash parameters &amp; injury mechanisms</td>
</tr>
<tr>
<td>Whole Body THUMS Validation In Controlled Crash Tests</td>
<td>Univ Virginia</td>
<td>Published THUMS vs PMHS sled tests (front/side)</td>
</tr>
<tr>
<td>Senior Driver Abdominal Injury Risk Factors</td>
<td>Virginia Tech</td>
<td>Published abdominal injury analysis &amp; metrics</td>
</tr>
<tr>
<td>Senior Driver Seating Position</td>
<td>Univ Michigan Trans Res Inst</td>
<td>Models for driver position, posture &amp; body shape</td>
</tr>
<tr>
<td>Mild Traumatic Brain Injury in Adolescents</td>
<td>CChIPS / NHTSA / SAFER</td>
<td>Determine correlation between impacts and injury outcomes from youth hockey league</td>
</tr>
</tbody>
</table>

### Post Crash Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Partner</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child Injury Database</td>
<td>Children's Hospital of Philadelphia</td>
<td>Pilot for improved crash data collection</td>
</tr>
<tr>
<td>Advanced Automatic Crash Notification</td>
<td>Wake Forest</td>
<td>AACN algorithm from EDR data</td>
</tr>
<tr>
<td>Development of a Dynamic Rollover Test - Kinematics of Initial Positions</td>
<td>Univ Virginia</td>
<td>Occupant/Vehicle kinematics from simulator</td>
</tr>
</tbody>
</table>
## Research Focus – Data Creation

<table>
<thead>
<tr>
<th>Active Safety Projects</th>
<th>Institution(s)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCS Performance Evaluation</td>
<td>UMTRI</td>
<td>Develop surrogate target &amp; test procedures</td>
</tr>
<tr>
<td>Pedestrian PCS Evaluation and Naturalistic Data Collection</td>
<td>TASI – Indiana / Purdue Univ Indy</td>
<td>Develop surrogate target &amp; pedestrian PCS test procedures</td>
</tr>
<tr>
<td>Lane Departure Warning Benefit Estimation</td>
<td>Virginia Tech</td>
<td>LDW evaluation scenarios and benefit simulation</td>
</tr>
<tr>
<td>Crash Data Archive</td>
<td>WATS</td>
<td>Data base for rear end, road departure and pedestrian crashes in Washtenaw County</td>
</tr>
<tr>
<td>Development of Standard LDW and LDP Test Method</td>
<td>VT / UMTRI / Ohio State</td>
<td>Detailed test procedure</td>
</tr>
</tbody>
</table>
Pedestrian Pre-Collision System Performance Evaluation

Naturalistic Driving Data Collection and Automatic Analysis Tool

- Pedestrian behavior study using 110 data recorder equipped vehicles in Indianapolis for 1 year
- In-vehicle data recorder DOD GS 600
  - Video, GPS, and vehicle speed
  - Resolution 1280x720 at 30 frame/sec
  - Angle 120°
- **93.6TB driving data** with about 1.44 million miles has been collected
- **Automatic tool for pedestrian detection in video image**
Pedestrian Pre-Collision System Performance Evaluation

Automatic Pedestrian Detection Algorithm from Naturalistic Driving Data

- Automatic background clutter measurement
- Background subtraction using generation of ROI (Region of Interest):
  - High accuracy (94%) pedestrian detection {HOG+LBP+Multimodal ELM method}
    - Generate pedestrian feature vector {size, length-width ratio, moving speed, distance orientation} for detection

HOG: Histogram of Oriented Gradient
LBP: Local Binary Pattern
ELM: Extreme Learning Machine
## Human Factors Projects

<table>
<thead>
<tr>
<th>Human Factors Projects</th>
<th>Partner</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver Distraction: Cognitive Model and Validation</td>
<td>Wayne State Medical School</td>
<td>Brain attention model</td>
</tr>
<tr>
<td>Demands of Voice Based In-Vehicle Interfaces</td>
<td>MIT Age Lab</td>
<td>Workload measures of voice interfaces</td>
</tr>
<tr>
<td>Teen Driver Coaching</td>
<td>VTTI</td>
<td>Impact of electronic coaching</td>
</tr>
<tr>
<td>Driver Distraction Algorithm, Operational Definitions and Database Development</td>
<td>VTTI</td>
<td>Algorithm and naturalistic driving database</td>
</tr>
<tr>
<td>Benefits of Brain Fitness Training Programs for Older Drivers</td>
<td>VTTI</td>
<td>Determine potential for UFOV training</td>
</tr>
<tr>
<td>Task Analytic and Time Series Analysis of Driver Behavior</td>
<td>Univ Iowa</td>
<td>Predict driver foot behaviors</td>
</tr>
<tr>
<td>Driver-vehicle interface for partially intelligent vehicles</td>
<td>Stanford Univ</td>
<td>HMI to improve driver understanding of vehicle state / situational awareness</td>
</tr>
<tr>
<td>Automated Tools for Naturalistic Driving Study Data Analysis for Driving Assessment</td>
<td>Univ California San Diego</td>
<td>Software tools to automate NDS analysis to create reduced datasets</td>
</tr>
<tr>
<td>Measuring Use and Impact of In-Vehicle Technologies on Senior Driver Safety</td>
<td>Univ of Iowa Medical School</td>
<td>Guides for new technologies (ie., ADAS) to be more helpful for senior drivers.</td>
</tr>
<tr>
<td>Teen Driver Survey</td>
<td>Univ Michigan Trans Res Inst</td>
<td>Surveys to investigate normative behaviors to improve driver education and outreach</td>
</tr>
<tr>
<td>Designing Feedback to Help Induce Safer Driving Behavior</td>
<td>Univ of Toronto</td>
<td>Create effective driver feedback systems (risky vs normal driver)</td>
</tr>
</tbody>
</table>
Example 1: Automated Tools for NDS Data Analysis

Background:

SHRP = Strategic Highway Research Program

SHRP2 collects NDS data to understand causes of traffic accidents to improve highway safety

Projection of SHRP2 Data Collection (2010 - 2013)

- NDS data of 3,000 drivers in 6 sites
- 2.5M trip files, 3,900 vehicle years
- 5 video views + sensor data ≈ 4PB of data

Manual reduction is impossible!!

SHRP2 NDS data collection sites (6)
Objective: Creation of Driver Distraction Dataset

1. **Define** Driver Distraction Categories

2. Using SHRP2 data, develop/refine **algorithm** for identifying epochs of distraction

3. Construct distraction and baseline **datasets**
   - The reduced datasets available to all researchers wanting to use SHRP2 data for in-depth study of distraction
Detecting epochs with eye-off-road time using “MASK”
Example 2: Driver Distraction: SHRP2 Dataset Creation

**Technology Transfer:**

- This dataset will provide a resource for better understanding of the link between driver distraction and crashes.

- With better understanding, effective countermeasures can be identified.
### Example 3: Automated Tools for NDS Data Analysis

**PI:** Dr. Mohan Trivedi  
**TRINA:** Pujitha Gunaratne  
**UCSD**

**Objective:** Computer Vision Software Tools to Automate Analysis of Naturalistic Driving Study (NDS) data

**Goals:** Produce markers on:

1. Distractive driver behaviors
2. Attention capture events in the environment
3. Crash risks based on situational awareness

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<tbody>
<tr>
<td>Progress Outreach</td>
<td></td>
<td></td>
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</tbody>
</table>

**Micro/ Macro Analysis**

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[Image of automated tools analysis]

[Image of micro/macro analysis]

[Image of goals and progress]

[Image of collaborative safety research center]

[Image of TOYOTA logo]
Automated Tools for NDS Data Analysis

Development of Tracking Tools: Hand Tracking

Use of edge features for hand motion tracking

Canny edge detection

Motion detection and accumulation based on edge image differencing

Recognizing 3 types of driver activity from tracking output (with fuzzy c-means clustering scheme)

Driver hand tracking with prominent motion segmentation and ellipse fitting
Appearance based action detection

• Identify the ROIs in the image corresponding to actions of interest
• Select features in each region for learning
Automated Tools for NDS Data Analysis

Development of Tracking Tools: Hand Tracking

Worked well with static lighting

<table>
<thead>
<tr>
<th></th>
<th>On wheel</th>
<th>Use gear</th>
<th>Use CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>On wheel</td>
<td>0.98</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Use gear</td>
<td>0.05</td>
<td>0.85</td>
<td>0.1</td>
</tr>
<tr>
<td>Use CD</td>
<td>0.04</td>
<td>0</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Poor results with dynamic lighting (moving shadows etc.)
Automated Tools for NDS Data Analysis

Development of Tracking Tools: Head Tracking

- 7FPs are: eye corners, nose corners, nose tip
- Head pose was estimated using Constrained Local Model (CLM)
Automated Tools for NDS Data Analysis

Application in Product Development

Driver distraction and situational awareness for future ADAS

<table>
<thead>
<tr>
<th>Warning</th>
<th>Action</th>
<th>Gaze</th>
<th>Object (Ped.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No (Green)</td>
<td>Driving</td>
<td>ON</td>
<td>Present</td>
</tr>
<tr>
<td>Hard (Red)</td>
<td>Driving</td>
<td>OFF</td>
<td>Present</td>
</tr>
<tr>
<td>Soft (Amber)</td>
<td>Texting/Drinking/Grabbing</td>
<td>ON</td>
<td>Present</td>
</tr>
<tr>
<td>Hard (Red)</td>
<td>Texting/Drinking/Grabbing</td>
<td>OFF</td>
<td>Present</td>
</tr>
</tbody>
</table>

Prototype Warning System

Situational Awareness

Intelligent HMI
Pillar 2: Crash Data Analysis

- Pre-Drive Culture
  - Education, beliefs / values

- Parking
  - Providing information & support

- Active Safety
  - Accident warning & avoidance

- Pre-Crash Safety
  - Damage mitigation

- Passive Safety
  - Passenger protection

- Emergency Response
  - Rescue

Vehicles

People

Traffic environment

New Data Sources
- Naturalistic Driving
- EDR

Existing Data
- NHTSA - FARS, CIREN, etc.
Research Focus

Integrated Safety Management Concept

Parking
- Driving information & support
- Back Guide Monitor
- Intelligent Parking Assist
- G-Book, G-Link

Active safety
- Accident warning & avoidance
- Radar Cruise Control
- Distance warning
- Lane Keeping Assist
- Lane Departure Warning
- AFS
- Night View
- Blind Corner Monitor
- Network Linked Navigation system

Pre-crash
- Damage mitigation
- VDIM Brake Assist
- Frontal Pre-collision System with Pedestrian Detection
- VSC / ABS
- Vehicle-Infrastructure Cooperative System

Passive safety
- Passenger protection
- GOA
- Rear-end Pre-collision System
- Seatbelts, airbags
- Pedestrian Injury-Reducing Body

Emergency response
- Rescue
- HELPNET
Pillar 3: Outreach – Actively Share

www.toyota.com/csrc
Thank you from Toyota
SHRP2 Overview

SHRP2 Safety Projects Timeline:

- **S08 NDS Analysis**
  - Phase I (4)  
  - Phase II  
  - S31: NDS Data Dissemination/User Support

- DSA (Data-Sharing Agreement) approved by TRB
Goal:

- Greatly increase knowledge of **driver behavior and performance** interact with environmental & vehicular factors
- Also increase knowledge of above factors’ **interactions on collision risk**

Current Status:

- **16,846** people contracted to participate in study
- **2,748** active participants
- Data collected so far –
  - **800,000 hours of driving**
  - **19 million vehicle miles**
- Preliminary findings
  - Most trips are between **noon to 6 pm**
  - Max deceleration ave. **0.3 - 0.4G**
  - **200 crashed** detected
  - More may be found as data is downloaded and analyzed