Automated Recognition of rear seat occupants' head position using Kinect™

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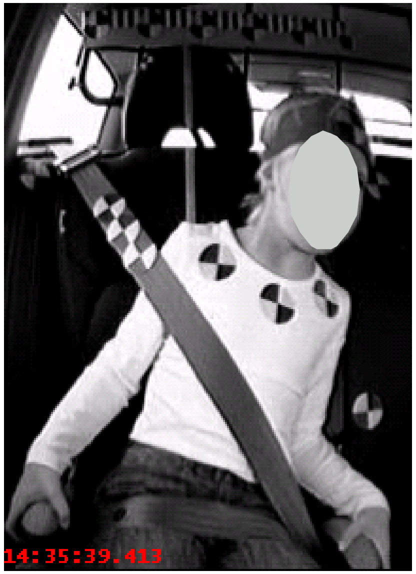
Background

- Child Restraint Systems typically evaluated using optimally positioned ATDs
- Real life: Children move: seat belt gets Out Of Position (OOP)



Sitting posture and belt position

- On-road driving situations – voluntary posture
  - Activity, Comfort/Discomfort, Possibilities to move freely
- Critical events / maneuvers – involuntary posture
  - Vehicle movement

Child’s behavior

Vehicle sudden
Maneuver

New Area of Research – Naturalistic Observation
Test track versus Every-Day paradigm

- **Test track and/or scripted maneuvers** in instrumented vehicle
  - Andersson M et al. Effect of Booster Seat Design on Children's Choice of Seating Positions during Naturalistic Riding. AAAM, 2010.
  - Jakobsson L et al. Older Children's Sitting Postures when Riding in the Rear Seat. IRCOBI Conference, 2011
  - Bohman K, et al. Kinematics And Shoulder Belt Position Of Child Rear Seat Passengers During Vehicle Maneuvers. AAAM, 2011.
  - Stockman I et al. Kinematics of Child Volunteers & Child ATDs During Emergency Braking Events in Real Car Environment.TIP 2013.
  - Stockman I et al. Kinematics and Shoulder Belt Position of Child ATDs During Steering Maneuvers. TIP 2013.
  - Osvalder et al. Older Children’s Seating Postures, Behavior and Comfort Experience During Ride. IRCOBI 2013.
- **Every day use: naturalistic study**
  - Charlton J et al. How Do Children Really Behave in Restraint Systems While Travelling in Cars? AAAM, 2010.

Multi-Center Naturalistic Study

Short term Goal: Develop **data collection and analysis methods** to observe/quantify position and posture of children while riding.

Long term Goal: Observe/quantify the **injury effects of suboptimal positions.**

Who	What	When
Children Hospital Of Philadelphia	Development of Kinect data collection software	August 2012 – January 2013
Monash University (Australia)	Study of children through instrumentation of 2 vehicles, for 2 weeks to 42 families.	August 2013 – October 2014
Children Hospital Of Philadelphia	Development of Kinect data collection software.Data analysis of logged data	October 2014 – April 2016
Autoliv Research (Sweden)	Sled test program with ATD to examine injury effects of sub-optimal positions	March 2016- June 2016

Vehicle instrumentation

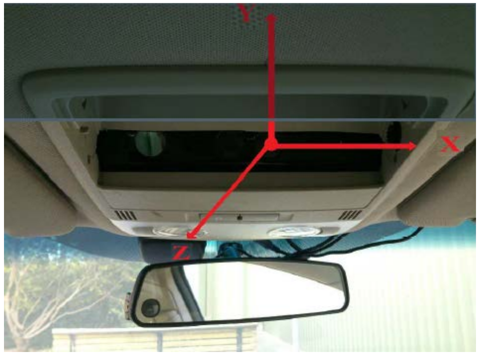
2 cars: 2006 Holden Statesman & 2007 Holden Calais

DAQ: Vbox (GPS, vehicle velocities, acceleration…)

Cameras (8)

Embedded PC + External Hard Drive

Kinect for Windows



Mobileye™

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6 cameras throughout vehicle

Forward scene camera

Interior cameras

Rear passenger camera

Camera Views

VBOX2 – captured driver/passenger data

VBOX1 – captured child data

Motion analysis with Microsoft Kinect™

- Gaming – Nov 2010
- RGB camera
- Depth sensor
  - Infrared laser projector combined with a monochrome CMOS sensor, captures video data in 3D.
- Angular field of view of 57°horizontally and 43° vertically
- Up to 30 frames per sec
- Inexpensive - ~$250

Kinect ™ Setup

- Automated start up, storing of data and shut down on vehicle ignition on/ignition off.

- Settings:
  - Near mode (500 mm to 3000 mm)
  - Seated mode
  - Color images 640x480 pixels (1 Hz)
  - Depth images 640x480 pixels (1 Hz)

- Collected 3D location of head, neck and shoulders of up to 2 seated rear row occupants
  - x/y resolution of 3 mm
  - Z resolution of 1 cm

Data Collection

- Participants
  - 42 families recruited over 14 months.

- Methods
  - Vehicle dropped off for 2 weeks– briefing session
  - 1 week data check
  - Vehicle pick up – debriefing
  - Demographic and Behavioral surveys

Kinect Data Collected

- 18 families from Statesman vehicle:
  - 1038 trips in Kinect-equipped vehicle
    - 690 hours of data
  - Average trip length ~ 10 min
  - Valid trips = a child present, travel >200m
    - 554 valid trips

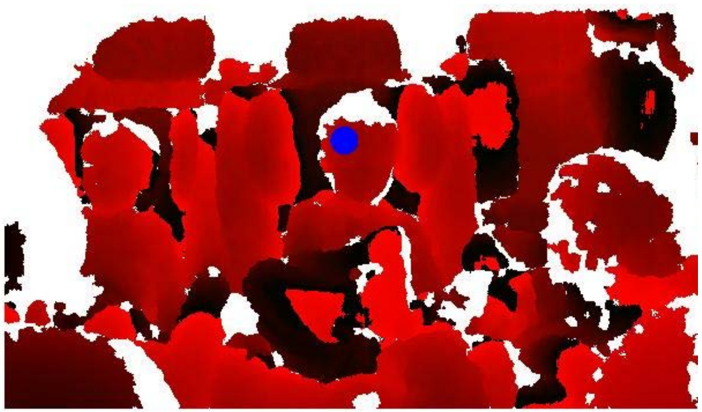
Kinect Data Processing Initial Efforts

- Plan A1
  - Utilize built-in skeletal tracking system of Kinect
- Plan A2
  - Identify frame of reference (baseline ‘perfect sitting’) and pixel depth distribution in region of interest
  - Manually review to confirm
- Plan B
  - Background subtraction process that filters out the vehicle seat and restraint from image
  - Look for circular shapes to identify head

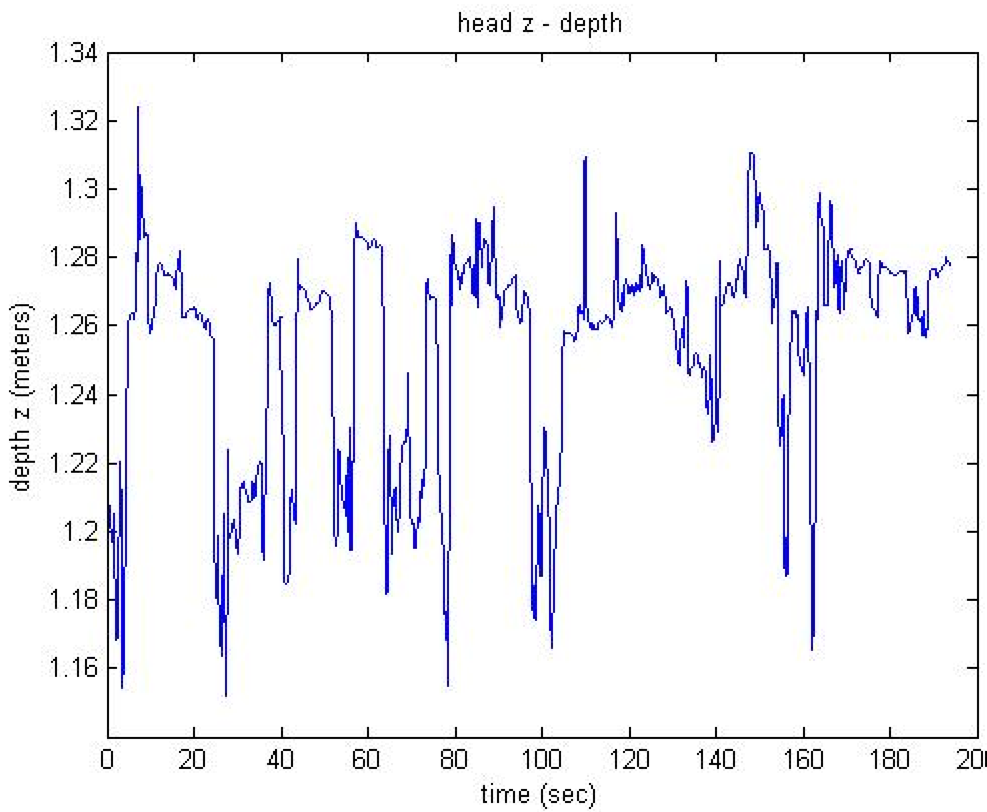
Kinect data processing

- Plan A1 = Kinect skeleton tracking -> x,y,z location of head/shoulders

Kinect data



- Depth of head motion quantified



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Plan A1 results

Great variability.

-Kinect algorithm unable to reliably recognize head

-Multiple skeletons seems unreliable

Skeleton sometimes absent

(sun reflection, confusion with head rest)

Validation Study

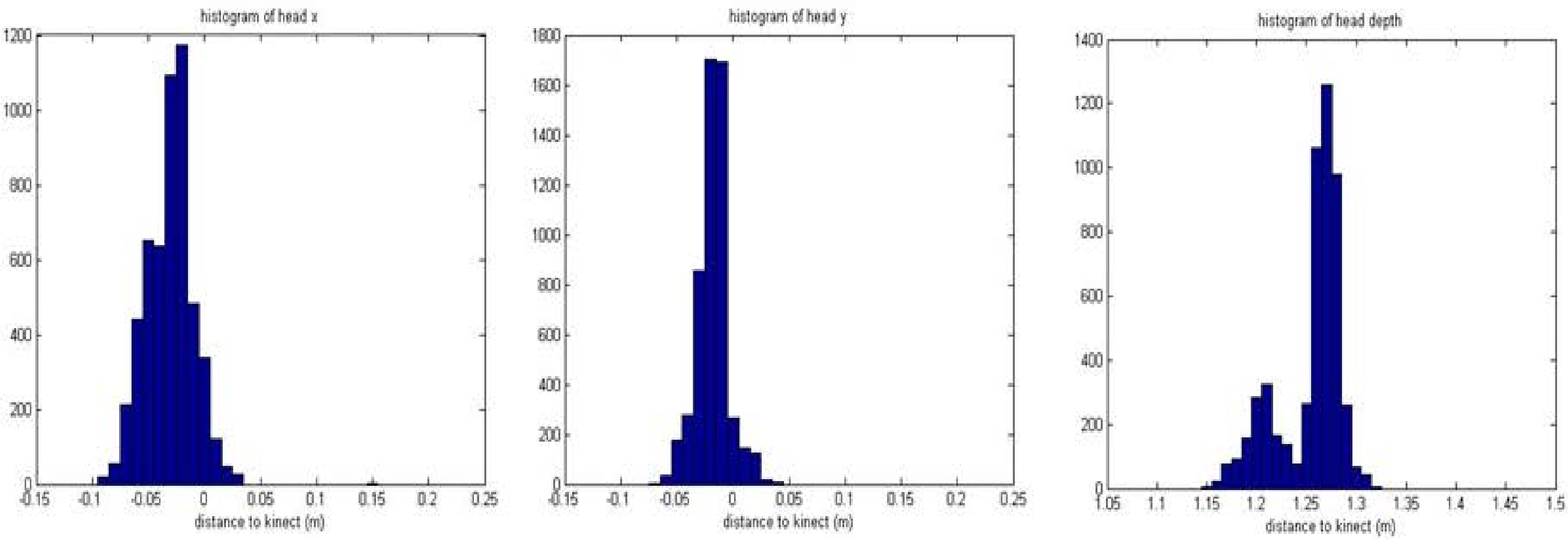
- 5% random sample of trips (~85 trips)
- Question: how often does the built-in skeleton recognition software accurately identify the head of the occupant of interest?

- Validation by comparing to manual frame coding.

- **Skeletal data was present 68% of the time** and of those, 3D head position was **successfully detected in approximately 41%**
  - ~30% of trips had valid head position data
  - For total sample, estimated at ~350 trips, 150K images

Kinect preliminary results

- One complete validated trip



Head depth distribution is bi-modal for Child Restraint System with wings.

Kinect Data Processing Initial Efforts

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  - Identify frame... ne motion compared t... istribution in region of in...
  - Manually re...
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  - Background ... ss t... ehicle seat and restraint from...
  - Look for circular s... s

None of these approaches were perfect

Final Analytic Process

Review each Kinect color image

- Via custom software
- 0.5 Hz

Manually identify location of head by clicking

- Identifies x, y position of the head from Kinect data
- Converted from image space to actual dimensions

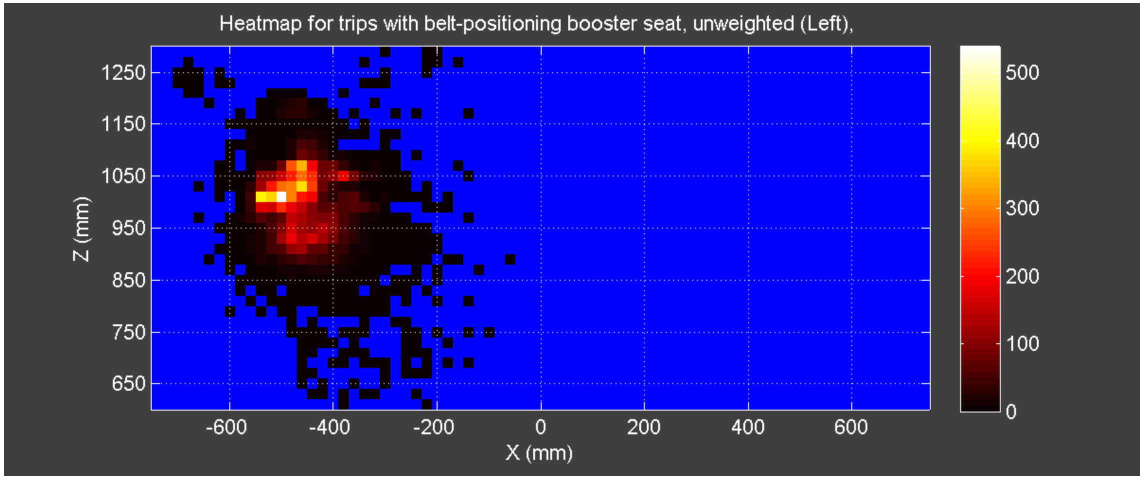
Extract z position (depth) corresponding to that x, y

- From Kinect depth data

Systematic analytic process

"Heatmap" of Head Position

- Looking from above
- X-axis – left right position; Z-axis – fore-aft position
- Color represents frequency of specific positions



n=3

Results will be presented at the 60th Annual Conference of the Association for the Advancement of Automotive Medicine (AAAM) in Hawaii, September 17-21 2016.

Sled tests

- Sled tests with ATD positioned in several of the OOP postures observed in naturalistic study
  - Conducted at Autoliv Research, Sweden
- Specifics of tests guided by set of preliminary tests conducted by Britax Australia (less complex sled, P-series ATD)

- Data collected included on board high speed video, ATD head/neck/chest metrics, belt forces, sled acceleration
- Analysis underway.

Conclusion

- Range of head positions for restrained child occupants **quantified for the first time** in a naturalistic setting
- Data can lead to solutions for optimal protection for those who assume positions that differ from standard test positions

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- Federal Aviation Administration*
- General Motors Holdings LLC
- Graco Children's Products Inc.
- American Honda Motor Co., Inc.
- Humanetics Innovative Solutions Inc.
- Lear Corporation
- mifold
- Minnesota HealthSolutions
- The National Highway Traffic Safety Administration*
- Nissan Technical Center North America Inc.
- Realtime Technologies Inc
- Safe Kids Worldwide
- StateFarm Mutual Automobile Insurance Company
- TK Holdings Inc.
- Toyota USA
- Transportation Research Center Inc.
- Volkswagen Group of America

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Thank you!

Questions?