



Data Mining to Detect Drowsy Driving

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The Drowsy Driving Problem

Fatigue is an impairment like alcohol or drugs

- Impaired reaction time, judgment and vision
- Problems with information processing and short-term memory
- Decreased performance, vigilance and motivation
- Increased moodiness and aggressive behaviors
- Increased “microsleeps” – brief (2/3 seconds) sleep episodes
- 18 hours sustained wakefulness produces performance impairment = .05% BAC



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The Drowsy Driving Problem

U.S.D.O.T. estimates : (Knipling, 1995)

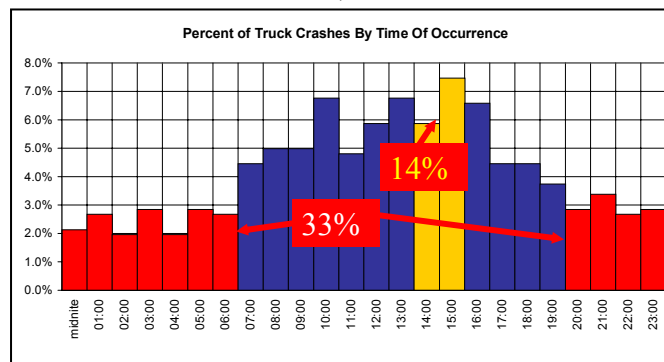
- 100,000 police-report drowsy driving crashes annually (2.6% of total)
- 1,550 fatalities (4%)
- 71,000 injuries
- \$12.5 billion in monetary losses
- Another 1 million crashes linked to inattention, which increases with fatigue
- These data are greatly understated as fatigue-causation is difficult to identify.

 United States Department of Transportation



Accident Data: U.S. Fatal Truck Accidents, 2002

- ✓ Driver fatigue is endemic, with nearly 50% of truck crashes occurring in late night or during mid-afternoon lapse (SAFESTAT data).
- ✓ Most carriers self-insure for >>\$100,000's.





Large Truckers: 30 months data- Accidents, Fatals, Injuries

Carrier/Size	Total Accidents	Fatal Accidents	Injury Accidents
A – 16,500	2,055	70	805
B – 8,923	1,431	49	648
Schneider – 12,153	1,317	48	587
D – 5,697	626	22	279
E – 3,868	627	20	258
F – 3,010	559	17	246
G – 2,805	242	10	129
H – 2,721	225	9	89
I – 2,641	355	7	139
J – 2,872	254	7	131



Driver Fatigue Indicators

Correlation of head motion and fatigue is widely recognized:

“Large head and body movements...were observed to be obvious indicators of fatigue.”

Source: FMCSA Report on Driver Fatigue Research at
<http://www.fmcsa.dot.gov/safetyprogs/research/driverfatigue.htm>



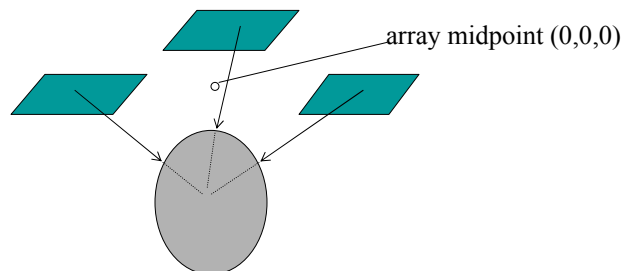
MINDS SENSOR ARRAY

- ✓ Adjacent electrode capacitors create “fringing” fields
- ✓ Array of 3 sensors - triangulate head position
- ✓ Sensor effective range of about 12” – optimum distance to top of driver head is 2” to 8”.
- ✓ Attach array to truck seatback – positioning the array at proper fixed distance above driver’s head.
- ✓ No known health concerns according to UNM School of Medicine study (current density is less than inherent physiological neuromuscular levels).
- ✓ Sensor operates at ~ 40 kHz, much lower frequency than most other devices in cab.
- ✓ Distinguishes occupied seat vs. unoccupied seat.



Triangulation Method

- ✓ 3 sensor array above driver’s head
- ✓ Proximity to head surface is adjusted for head radius - thus providing approximate “electronic center” of occupant’s head
- ✓ Head position XYZ coordinates are expressed with respect to array midpoint





ASCI MINDS Truck Installation



Assumptions

- ✓ (Anomaly Detection) Drowsy behavior is different from wake behavior on time scales of several minutes.
- ✓ Drivers are not asleep when they are making large, quick motions (glancing at mirrors, adjusting radio, etc.) over a minute time-scale.
- ✓ Drivers may be approaching sleep if they exhibit large, slow motions (y-drift) over a minute time-scale.
- ✓ Drivers may be approaching sleep if they become very still on several second time-scales after making large, quick motions.
- ✓ Drivers may be approaching sleep if they exhibit micro-nods at time-scales of a second.



MINDS Algorithm

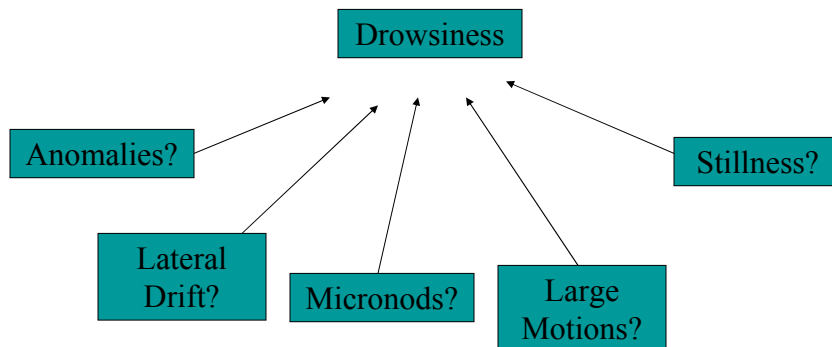


We have developed a system that analyzes 5 patterns of drowsy head motion:

- 1: Anomaly detection — is head motion similar to baseline within the last 5 minutes?
- 2: Y-drift — are there slow lateral movements with the last minute?
- 3: Micro-nod — are there small nods within the last few seconds?
- 4: Large motion — have there been large movement, such as rubbing face/eyes, within the last minute?
- 5: Stillness — is there a stillness after a large motion within the last few minutes?



No single indicator is sufficiently indicative to trigger an alert. But together there is enough information





Composite Output

- ✓ Each pattern-detector outputs a probability of wakefulness (close to 0) or drowsiness (closer to 1).
- ✓ The 5 outputs are combined to yield a composite assessment of drowsiness, from 0 to 1.
- ✓ The composite is then compared to a threshold value derived from the specific driver's "awake" condition which is learned during the initial 20 minutes of the trip.
- ✓ We use 2.5 standard deviations (of the "awake" output) as the pre-set threshold for warning signal.
- ✓ After the 20 minute "training period" the driver can adjust sensitivity of the system - for **alertness self-monitoring**.
- ✓ By providing **alertness self-monitoring**, the driver is actively engaged and less likely to disregard warnings.



The encoding

- ✓ The five assumptions can be encoded into five functions that in a multiplicative fashion generate a drowsy detector .
- ✓ Phi's values are between 0 and 1, where 0 indicates wakefulness and 1 indicates drowsiness. Each function is a detector for one sleep indicator.
- ✓ The exponents can be used to tune the detector. An exponent of zero turns off a particular detector. A coefficient of infinity makes the detector very sensitive.

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Experiment

- ✓ Research data used to develop the software detector was provided by Carnegie Mellon University - National Robotics Engineering Consortium, under contract from Johnson Controls, Inc.
- ✓ Each subject was instructed to obtain a normal night's sleep prior to the day of the test, then drove the simulator from approximately 11am-noon, 3pm-5pm, and either 2am-5am (n=9) or 3am-5am (n=4).
- ✓ The subjects were drawn from a sampling of the adult driving population without regard for age, sex, or occupation (however, many of the subjects were school teachers on summer vacation).
- ✓ The simulator was configured to drive like a mid-size US passenger car, except for the seat, steering wheel, and side mirrors, which retained truck-like characteristics. The simulator motion base was not used, to give the "feel" of a smooth car ride.



Real-time data included

- ✓ 1. Eye coordinates and eye closure obtained from a Carnegie Mellon infrared camera using retinal reflectance.
- ✓ 2. PERCLOS, a one-minute calculation of slow eye closures, using > 80% eye closure (pupil obscured).
- ✓ 3. Sensor voltages from the ASCI overhead capacitive sensor array.
- ✓ 4. Video showing the right front of the driver's face.
- ✓ 5. Simulator data (speed, lane tracking, wheel angle, turn signal use, etc.).



Data Processing

- ✓ The sensor voltages were post-processed by ASCI to derive head position XYZ coordinates.
- ✓ Simulator data was post-processed by Carnegie Mellon to derive relevant vehicle data, particularly one-minute averages of speed, lane departures, and lane deviations.
- ✓ The researcher maintained logs of significant driver or simulator events such as the subject's PERCLOS level, signs of wakefulness or drowsiness (yawns, etc.), and noteworthy vehicle simulator events (swerving, speeding, and the like). These logs were not part of the original research protocol but became an important supplement to the primary data stream.



Comparison with current state-of-the-art

- ✓ After the ASCI MINDS detector was developed, its output was compared to PERCLOS, which has been scientifically validated as a long-term measure of driver drowsiness.
- ✓ Thresholds were selected to allow a determination if either detector provided advance detection of driving "errors" noted in the simulator logs kept by the research manager.



Results of Driver Simulation

Driver	# of Events	# Perclose Detection	% Perclose Detection	# MINDS Detections	% MINDS Detection
8	3	0	0%	3	100%
23	11	5	45%	7	64%
31	6	6	100%	6	100%
33	2	1	50%	0	0%
35	1	0	0%	1	100%
59	2	2	100%	2	100%
62	3	2	67%	3	100%
66	1	0	0%	0	0%
68	6	1	17%	6	100%
71	3	3	100%	3	100%
Total	38	20		31	
Percent	100%		53%		82%



Results

- ✓ Overall, MINDS had a 100% advance detection rate for 7 of 10 drivers, and detected 31 of 38 or 82% of driving “errors” (significant lane deviations, sudden speed changes, etc.)
- ✓ PERCLOS had a 100% advance detection rate for 3 of 10 drivers, and detected 20 of 38 “errors” (53%).
- ✓ Of the seven “errors” missed by MINDS, four were on the margin or just below the selected threshold.



Driver Notification

- ✔ Provide continuous read-out of driver's relative fatigue (scaled 9 to 1)
- ✔ When display = 4, activate audible notification.
 - Low level: 100 samples (10 seconds) over 5 minutes.
 - High level: 250 samples (25 seconds) over 5 minutes.
- ✔ Can implement other in-cab notification devices.
- ✔ Can implement real-time remote notification (e.g. via Qualcomm link).

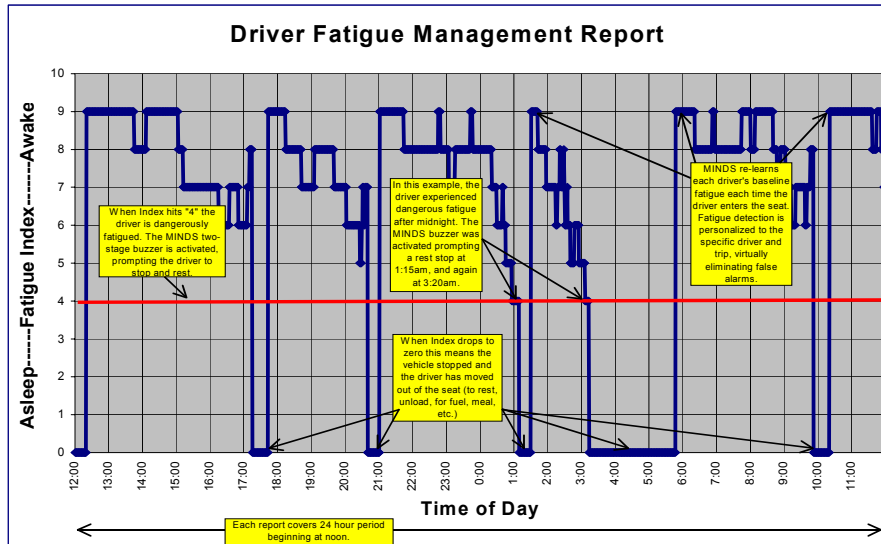


MINDS Reports

- Log 4 weeks of truck & driver data
- Record alertness display in one minute intervals
- Tracks separate driving sessions
- Tracks total driving time
- Tracks total alert driving minutes
- Tracks number of warnings issued
- Data easily linked into worksheet / database
- 3 Report Modes: full, summary, executive
- Data transfer methods: either connect a laptop in-vehicle, or in-office (could swap-out boxes to simplify the process).
- Upgrade plan - utilize Qualcomm or other real-time communications link to capture data on demand or when urgent.



MINDS Sample Report (24 hour period)



MINDS Advantages

- ✓ **The Most Reliable Fatigue Sensing Technology.**
- ✓ **Fully Automatic**
- ✓ **Management Report Capable**
- ✓ **Peace of MINDS™**