iLid: Low-power Sensing of Fatigue and Drowsiness Measures on a Computational Eyeglass

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Why Measure Fatigue?
How Do We Measure Fatigue?

- Percentage of Eye Closure (PERCLOS)
- Blink Duration
- Blink Frequency
Why Not Use Existing Technologies?

We need:
- Low-power
- Portable
- Accurate
- Robust
The Challenge for Reducing Power Consumption

Problem: Digitizing and processing too many pixels
iLid

Contributions:

• Accurate measure of fatigue parameters at low power

• Robustness to lighting, mobility, and other variabilities
iShadow

ARM Cortex M3

Stonyman Vision Chip
Computational Pipeline

Upper Eyelid Detection

Blink Detection

Drowsiness Estimation

PERCLOS Blink Duration Blink Rate
Upper Eyelid Detection

sub-sampling → filtering & edge detection → de-noising → detecting upper eyelid position
Blink Detection

Sequence of Eyelid Positions

Template Matching

Logistic Regression Classifier

Detected Blinks
PERCLOS: the percentage of frames when the eyes are more than 80% closed excluding the blinks. (NHTSA 1999)
Evaluation

• Aggregate Results
• Robustness to Variabilities
• Comparison against JINS MEME
• Power Consumption
Aggregate Results

16 subjects
5 minutes of watching a video clip
indoor & outdoor

<table>
<thead>
<tr>
<th>Blink</th>
<th>Precision</th>
<th>Recall</th>
<th>F1 score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor</td>
<td>0.96</td>
<td>0.85</td>
<td>0.90</td>
</tr>
<tr>
<td>Outdoor</td>
<td>0.95</td>
<td>0.84</td>
<td>0.89</td>
</tr>
</tbody>
</table>
Robustness

illumination

movement

eyeglass shifts
iLid is Robust to Illumination Changes
iLid is Robust in Mobile Settings

5 subjects
5 minutes of eye video
watch a video clip vs. walk on a treadmill
iLid is Robust with Eyeglass Displacements

5 subjects
5 minutes of watching a video clip
spacer sizes: 0.5, 1, and 1.5 cm
Comparison against JINS MEME

Electrooculography
Power Consumption

Frame rate = 100 Hz
Power consumption = 46 mW

iLid has low power consumption even at high frame rates of 100Hz
Conclusion

- iLid can obtain fatigue and drowsiness detectors in real-time and under natural environments.

- iLid is robust to user mobility, lighting conditions and eyeglass shifts.

- iLid has wide applicability and can enable fatigue sensing in domains ranging from transportation safety to cancer fatigue.

Thanks & Questions?