Eye Tracking System and Mental Load Estimation

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Background and Motivation

Introduction
The relationships between eye activity and mental load are of great interest in the cross fields of DSP, Machine Learning and biotechnology. For instance, if a pair of smart glasses can identify whether its user’s mind is heavily loaded or not based on their eye behaviors, it can then help them reschedule their agendas and delay all notifications until the user’s mental load level returns to low to avoid causing any interruption of an undertaken task.

Aims and Objectives
To apply a top down design to build low cost accurate and robust eye-tracking system:
- Selecting and modifying a low-cost web-camera
- Evaluating and applying selected algorithms
- Adding improvements to current algorithms

And then to achieve mental load estimation by:
- Designing appropriate cognitive and perceptual load tasks
- Collecting data from potential users
- Using proper statistical models to investigate relationships between pupillary responses and mental loads

Methods

A top-down approach system design

1. Head-mounted Web-camera
   - 30 FPS low-cost USB web-camera for recording.
   - Infrared LEDs added for distinguishing pupil region
   - Visible light filter to minimise impact of illumination variation
   - Attached to frames via flexible metal arm

2. Processing
   - Blob identification and edge detection: Improved Haar-like feature, Sobel+GS blur, Canny edge,
   - Better noise removal for corneal reflection and eyelashes: Cascade Morphological operation
   - Improved blink detection: K-mean clustering method and early return

3. Outputs and visualisations
   - Real time video sequence playback with:
     - Blink detection state machine
     - Current frame histograms for blink detection

4. Mental load estimation
   - Detailed classifications of the impact of cognitive load (C.L) or perceptual load (P.L) only on eye activities have been done (yellow region), but the green region which takes into account both P.L and C.L has not been explored extensively in previous papers. (L = LOW; H = HIGH)

Mental task design and data collection

- Environment: MATLAB’s GUIDE
- Participants: 12 Uni students (10 male 2 female)
- Task duration: approx. 45 min
- Devices required: laptop, mouse and web-camera.
- Outputs & feedbacks: Integrated in MATLAB and stored in CSV files

Evaluation and Discussion

Algorithm Speed, Robustness and Accuracy

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Time per Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chen’s</td>
<td>4.4ms</td>
</tr>
<tr>
<td>Integral image</td>
<td>6.03ms</td>
</tr>
<tr>
<td>Haar-like responses</td>
<td>0.40ms</td>
</tr>
<tr>
<td>Blink detection</td>
<td>0.49ms</td>
</tr>
</tbody>
</table>

Our algorithm is robust against eyelashes, glasses and corneal reflections.

Conclusions

The price, speed, robustness and accuracy of the eye tracking system are improved. The classifications do show some relationships between eye activities and both perceptual and cognitive loads invoked in one task but it is not always consistent. Further investigation is needed for rigorous proof.

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