Eye Detection and Pupil Tracking for ALS Patients

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Abstract

The goal of the pupil tracking project is to provide a method of communication using eye movement for people with Amyotrophic Lateral Sclerosis (ALS) who are unable to control voluntary muscle movement in their limbs. We use Matlab in order to prototype the process of eye detection and pupil tracking. We also focus on the real-time implementation to achieve processing speeds of fifteen frames per second, initially and thirty frames per second later on. Such high speeds are required to match the recording speed of the camera.

Overview

Goal
Develop an algorithm that tracks the movement of the pupils.

Steps
- Eye Region Extraction
- Homomorphic Filtering
- Eye Detection
- Kalman Filtering

Eye Region Extraction

This portion uses the horizontal and vertical projections of the gradient to find the biggest changes in intensity. These changes correspond to edges in the image.

Horizontal Projection
- Goal: Use peaks near the eyebrows and the bottom of the eye to define the top and bottom of the region.
- Issues: The hairline on the forehead and the lips are often a large peaks, so these must be taken into account.

Vertical Projection
- Goal: Find the peaks near the edges of the face to define the left and right parts of the region.
- Issues: This is more consistent although making sure that the peak cannot be found within a certain distance from another adds consistency.

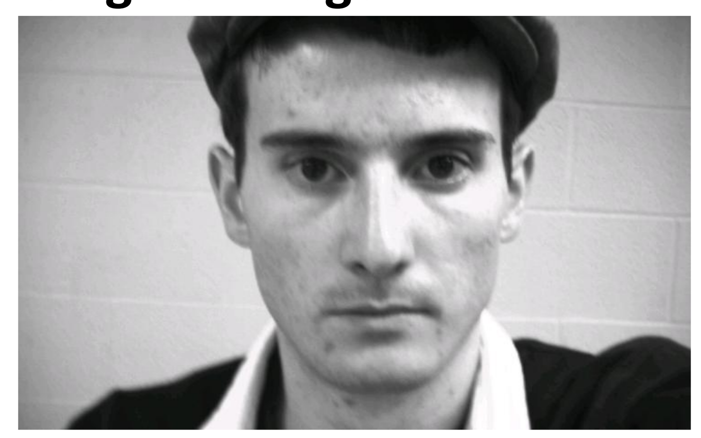
Homomorphic Filtering

- Homomorphic filtering performs filtering on an image by simultaneously normalizing the brightness and creating more contrast.
- This is accomplished using a high-pass filter on the natural log of the image.
- For the eye tracking problem, the homomorphic filter is able to separate the useful information of the image from the artifacts created by non-uniform lighting conditions.
- The filtering removes the artifacts, leaving a clearer picture of the eye region.

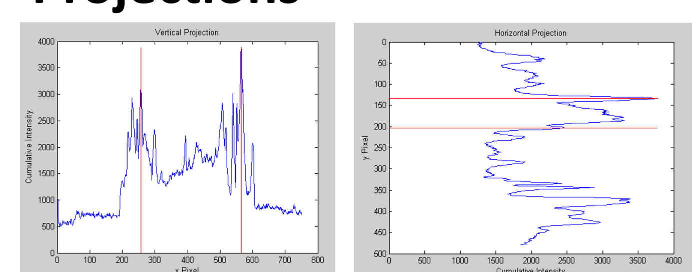
$$Image(x,y)$$
$$\downarrow$$
$$ln$$
$$\downarrow$$
$$FFT$$
$$\downarrow$$
$$H(u,v)$$
$$\downarrow$$
$$(FFT)^{-1}$$
$$\downarrow$$
$$exp$$
$$\downarrow$$
$$ImageOut(x,y)$$

Steps

Original Image

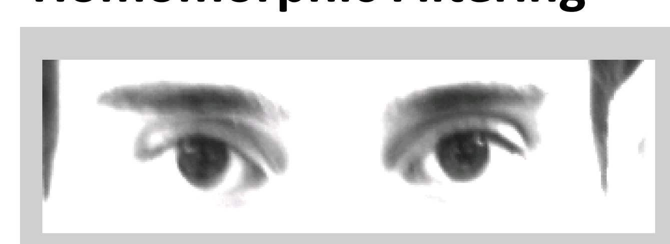


Projections

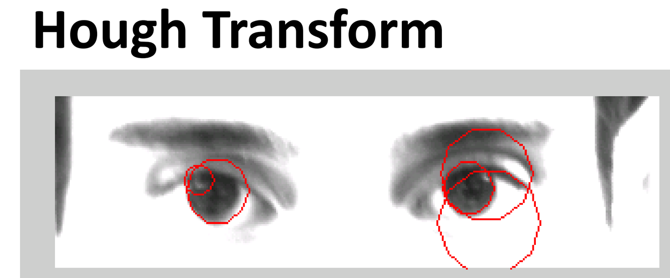


Eye Region Extraction

Homomorphic Filtering

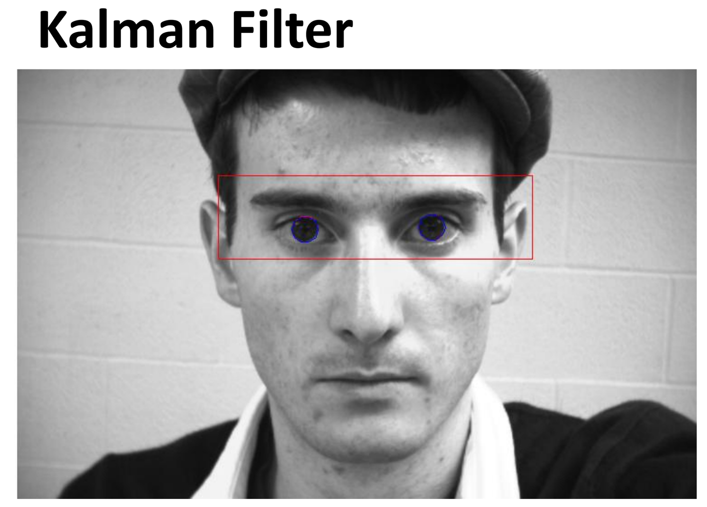


Hough Transform



Eye Verifier

Kalman Filter



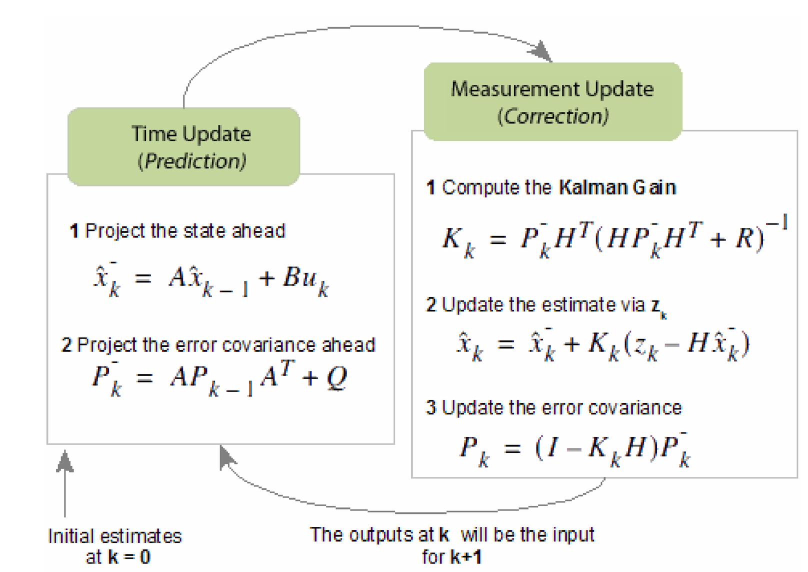
Eye Detection

Hough Transform
- The Hough Transform finds features within an image, generally simple shapes such as lines or circles.
- In the eye detection problem, the Hough Transform finds circles within the region that has been extracted and filtered. These circles correspond to the pupils.

Eye Verifier
- After locating circles, an eye verifier checks all circles that are found and decides which two have the correct characteristics of the eyes based on size and distance from one another.
- Once the eyes are verified, we will use their location as our measurement for the Kalman filtering stage

Kalman Filtering

- Kalman filtering estimates the state of a dynamical system at each time using the measurements obtained up to that time.
- It proceeds in two stages:
  - **Prediction**: In this step, we predict the location of the eyes using the past estimate and the state transition model.
  - **Update**: In the update step, we will use the current measurement to refine the predicted state.
- The estimates gained from the Kalman filter are generally more precise than the individual measurements since they consider both the current and the past measurements.



Conclusions

- We developed a robust pupil tracking system which can be used in commercial application that use eye motion for various applications.
- In the future, we will improve the speed of the algorithm to be able to use it in real-time.

References

- K. Peng, L. Chen, S. Ruan, G. Kukharev. A Robust Algorithm for Eye Detection on Gray Intensity Face without Spectacles. JCS&T Vol. 5 No. 3. 2005, 127-132.
- Q. Wang, J. Yang. Eye Location and Eye State Detection in Facial Images with Unconstrained Background. Journal of Information and Computing Science Vol. 2 No. 3. 2007, 209-214.