Building an Eye Tracker

Project Proposal
Cognitive Science(SE367)

Aim

In this project we aim to build an open source head gear with purpose of eye tracking using a webcam, Safety Goggles and Infrared emitters. Target specifications of the device are desired as:

- **Speed** : 30 Hz or 30 frames per second
- **Accuracy**: 15x15 pixels or ~70x60 dots on a laptop screen with resolution 1280x800
- **Open Source**: All design components should be available free from licensing or with some form of GPL
- **Standard API**: Must use API described in [3]

Previous Trackers

- ITU gaze tracker [1] is an offline system which packs all processing equipment into a backpack allowing the user to carry system anywhere. This system can be utilized to identify gaze patterns in scenarios such as driving, buying in market or painting. Hence it can be used for researches aiming to classify changes in patterns with learning. Attached below is a picture of ITU's gaze tracker.

- SMI iViewx HED: A commercial head mounted eye gaze tracker currently in use by Centre of Behavioural and Cognitive Sciences (CBCS, Allahabad). Equipped with two cameras, this tracker allows one to see what the user is seeing, with gaze points embedded on it.
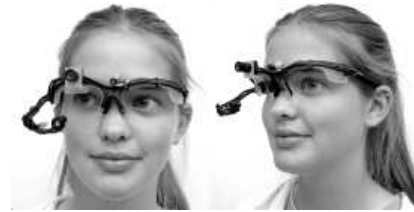
Design description (preliminary)

Unlike above described trackers we want to do all processing on an external computer. Hence the head gear will have a laser pointer and two web cameras. The complete system will be mounted on lab goggles which are easily available. Working can be described as follows:

1. Laser pointers project circles on surface facing the user. These circles are distorted into ellipses due to the angle between user and surface as shown in figure on right side[1].
2. A camera captures the distortion of ellipses. These images are used to estimate head pose with respect to wall. (H)
3. The head gear remains fixed with head. Another camera(IR capable) on gear takes images of eyes. These images are used to determine changes in pupil location(P)
4. The above obtained location of head and pupil wrt head are used to determine gaze of user

Thus, project can be broadly divided into five parts to be done in the order stated:
1. Construction of head gear with one IR capable camera and IR leds [Hardware]
2. Obtain location of pupil P with respect to head gear using image processing [Programming]
3. Adding one more camera and a laser pointer to head gear [Hardware]
4. Using laser pointer and one camera to obtain H [Programming]
5. Combining H and P to obtain gaze point G [Programming]

Construction of Head gear

Material required :
1. One Safety Goggle
2. 2 web cameras with image resolution of atleast 640x480
3. IR leds and a circuit to power them from USB of cameras
   (this will reduce wire clutter and weight)
4. Wire and hollow rods to make stand which will mount cameras on goggle
5. Strong Duct tape or sealing agent

Programming

To interface with camera and to do image processing we will use C++ with OpenCV, which is a fast and open-source library. User interface for training purposes will be programmed in Python using Glade.

Algorithm to be used for part 2 (Obtain location of pupil P from head image)

- Since eyes and head are fixed with respect to camera, only pupil,sclera and iris can move.
- Under IR light pupils look as shown in the image on right
- First we detect eyes from this image using Haar templates for eyes
- Then using an adaptive moving window algorithm, we detect largest white and round blob in the eye image. This should give us the pupil
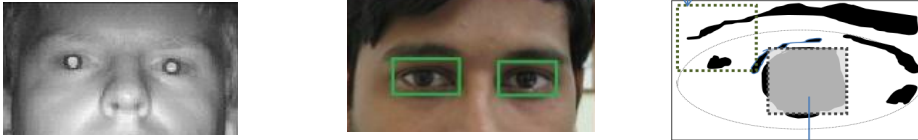
In **Eye image (BI$_E$)** , pupil can be detected using a moving window of size approximately equal to pupil. Pupil size is estimated from size of eye obtained. We use an O(kn) dynamic algorithm for moving window :

1. Construct a white moving window(**W**) of size placed at (x,y) on **BI$_E$** where k is estimated diameter of pupil
2. Calculate correlation of **W** with image pixels of **BI$_E$** using   as **W** is zero everywhere
3. Store correlation for $(x,y)^{th}$ pixel in another image
4. Move window from (x,y) to (x+1,y). The correlation change can be calculated by looking at x^{th} column of previous and $x+k+1^{th}$ column of recent window:
5. Determine position with highest correlation. This will be the location of pupil.

Test Subjects and conditions

While programming, the algorithm will be tested on various subjects in different conditions. Subjects are classified by their skin tone and eye color. Conditions differ in ambient light and movement of head allowed.
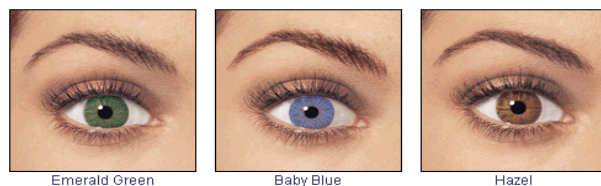
1. **Varying skin tones**
   - Celtic
   - European (Light , Dark)
   - Mediterranean
   - Brown
   - Black
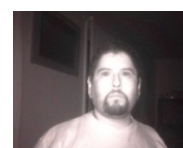

2. **Different IRIS color**
   - Amber
   - Blue
   - Brown
   - Hazel
   - Gray
   - Green

3. **Light conditions**
   - Daylight
   - Flouroscent light
   - Dark (with IR only)

   Ambient light conditions are to be tested with IR Led and without IR led

4. **Movements (Useful for 3,4,5th step of construction)**
   - No head movement
   - Vertical head movement
   - Horizontal head movement
   - Free head movement

References

[1] BABCOCK, J. S., AND PELZ, J. B. 2004. Building a lightweight eyetracking headgear. In Proceedings of the 2004 symposium on Eye tracking research & applications, ACM, San Antonio, Texas, 109-114.

[2] JAVIER SAN AGUSTIN, HENRIK SKOVSGAARD , MARIA BARRET, MARTIN TALL, DAN WITZNER, Evaluation of a Low-Cost Open-Source Gaze Tracker ,Proceedings of the 2010 symposium on Eye tracking research & applications, ACM , Austin TX

[3] CRAIG HENNESSEY, ANDREW T. DUCHOWSKIY, Expanding the Adoption of Eye-gaze in Everyday Applications, Proceedings of the 2010 symposium on Eye tracking research & applications, ACM , Austin TX

[4] Cohen, A. S. (1983). Informationsaufnahme beim Befahren von Kurven, Psychologie fÃƒÂ¼r die Praxis 2/83, Bulletin der Schweizerischen Stiftung fÃƒÂ¼r Angewandte Psychologie