Project Proposal: Synthesizing an Eye Gaze Vector from a Multi-Camera View

A senior project for CPSC 490 by Kevin Kirk
Faculty Advisor: Katherine Tsui
Yale University Social Robotics Lab

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Background / Motivation

The Social Robotics Lab at Yale develops a wide variety of computational models for embodying human behavior, using socially assistive robotics to offer a unique approach towards answering a range of questions about social development. For example, the lab uses programmable robots to determine how hearing-impaired infants best learn sign language. By programming human-like interactive capabilities into robots, such as aligning head movements and lines of sight to match those of an infant subject, we can gain insight into sign language acquisition and even aim to supplement the learning itself.

This project is designed to build one component of the infrastructure for such research. In particular, I will be focusing on synthesizing an eye gaze vector from data points representing a participant’s facial features. I will use this eye gaze vector to establish a “mutual gaze” between a robot and the participant.

Project Design

Overview:
I will build a framework for these infant studies, using existing Timm and Flandmark facial recognition software to program interactive movements into a MAKI robot (described shortly). Using data points gathered from three Logitech web cameras, I will approximate the subject’s eye gaze vector and use the MAKI robot’s existing servomotor functions to align the robot with the subject’s line of sight, establishing a mutual gaze between the two. Once mutual gaze has been established, I will then use the robot’s head panning to follow the subject’s shifting eye gaze.

Existing Components:
This work will take advantage of several existing technologies in the Social Robotics Lab. Firstly, the MAKI robot is already assembled. MAKI is a 3D-printable robot, approximately 1/3 meters high and and programmable through an Arbotix controller. This robot is also already equipped with five Dynamixel Servo motors (head pan, head tilt, eye pan, eye tilt, and coupled eyelid manipulation) that will be programmed to provide social interactivity with the participant.

In addition, the Social Robotics Lab already has facial recognition software available that will provide data points corresponding to the subject’s facial features. Three webcams are currently linked to an Ubuntu machine and can produce output that includes float locations of the eye corners,
center, pupil, nose, and mouth corners. The tracking server will be connected via USB to the MAKI robot’s controller, eventually allowing for programmed movements based on the subject’s gaze. For the purposes of this project, rather than testing the calibration’s functionality on infants I will be implementing the design using adult humans as test subjects. This will allow for easier calibration of the camera system and algorithm implementation for synthesizing the eye gaze vector.

Finally, there already exists a github repository, coded mostly in C++. The code uses both an open-source implementation of the Timm algorithm, which calculates a subject’s pupil location by taking the maximum intersection point of image gradients around the eye, and the Flandmark library, which outputs data points corresponding to a person’s eye corners as an instance of the structured output problem. The repository requires ZeroMQ for message passing, and relies on the OpenCV library for functions underlying both algorithms.

Figure 1: An example of the Timm pupil tracking algorithm (blue pixels) and the Flandmark eye tracking (red) being used on a subject from three different vantage points.

Deliverables:
In order to track my progress on the objectives below, I will be meeting weekly with project supervisor Kate Tsui. I expect to complete the vast majority of my work on-site in the Social Robotics Lab, as many of the tasks below are at least somewhat hands-on in nature and require familiarization with the hardware in use.

I will prepare a written report of all tasks accomplished and will also give an oral presentation at the Social Robotics Lab in early December.

Primary Goals:
1. Calibration Procedure

- Design a calibration procedure for the three Logitech C525 webcams as well as a calibration of the robot’s and participant’s location, working in an environment approximating that of an eventual clinical study. This will include an intrinsic calibrations to ensure the functionality of each individual webcam, followed by an extrinsic calibration to coordinate all three cameras in a system.

1Detailed descriptions of these algorithms can be found in Accurate Eye Centre Localisation by Beans of Gradients by Fabian Timm and Erhardt Barth and Detector of Facial Landmarks Learned by the Structured Output SVM by Michal Uríčář, Vojtěch Franc and Václav Hlaváč. The Timm and Flandmark Algorithms have been used successfully in the Social Robotics Lab with infant, 11 months old.
2. **Eye Gaze Vector**
   - Research potential methods of synthesizing an eye gaze vector and decide one that can be best implemented.
   - Using data points from the Timm and Flandmark facial recognition algorithms, output a vector approximating the participant’s line of sight.

3. **MAKI Head Movement**
   - Using the MAKI robot’s existing Dynamixel Servo Motors for head panning, program two main behaviors:
     - Detect when the subject is looking at the robot and establish a mutual gaze
     - When the robot is not being looked at, return to a default pose.

**Stretch Goal:**

1. **Refine the MAKI Interactivity**
   - Change to "once established, follow the subject’s shifting eye gaze."
   - Once mutual gaze has been established, follow the subject’s shifting eye gaze using head panning.
   - Add the ability for head tilt with the eye gaze vector, improving on the basic implementation of an estimated alignment.

**Timeline**

**September**

9/30 Compile a list of potential algorithms to use for the eye gaze vector

**October**

10/20: Finalize the camera calibration procedure

10/21-10/25: October recess

10/31: Select and implement an algorithm for the eye gaze vector

**November**

11/20: Coordinate MAKI head movement for a mutual gaze

11/21-11/29: Thanksgiving break

11/30: If time allows, program more involved interactivity into the robot

**December**

12/5 Prepare and present an oral presentation

12/16 Submit all final project materials