Department of Computer Science & Engineering
The University of Texas at Arlington

Architectural Design Specification
CSE 4316: Senior Design I
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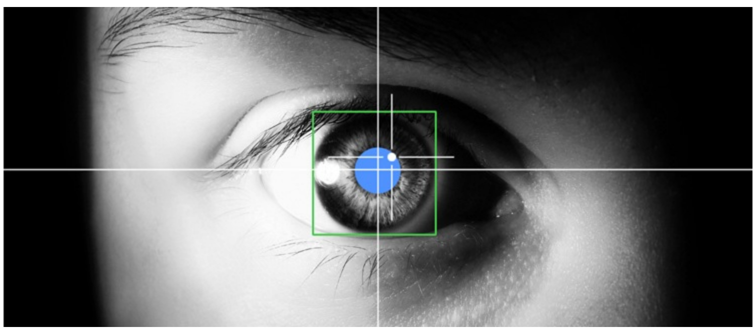

Eyeronic
Eye Tracker

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REVISION HISTORY

Revision	Date	Author(s)	Description
0.1	11.18.2015	KM , JS , ZA , FN , JT	Created Document

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1 Introduction

This product shall have three layers that work in unison to track the pupil of the user. The three layers in our system are the Software layer, Daughter Board, and the Jetson TK1. The three layers will be discussed more in the following sections.

2 System Overview

The system consists of three major layers which are: The Daughter Board Layer, The Jetson TK1 Layer, and the Software Layer. The Daughter board is the main interface between the MIPI camera module and the Jetson TK1. It contains the OmniVision 5640 sensor that interfaces to the Jetson TK1. The Jetson TK1 layer provides the interface between the MIPI camera and the USB. This layer is what communicates with the computer and the Daughter board. It uses USB to power the device and transfer the data to a computer. The Software layer takes input from the Jetson Interface, processes that data, and tracks the pupil movement in real time. Various Computer Vision algorithms such as the Canny Edge Detector, Gaussian Smoothing, and the Random Sampling Consensus are implemented by the software layer to accurately track the pupil movement.

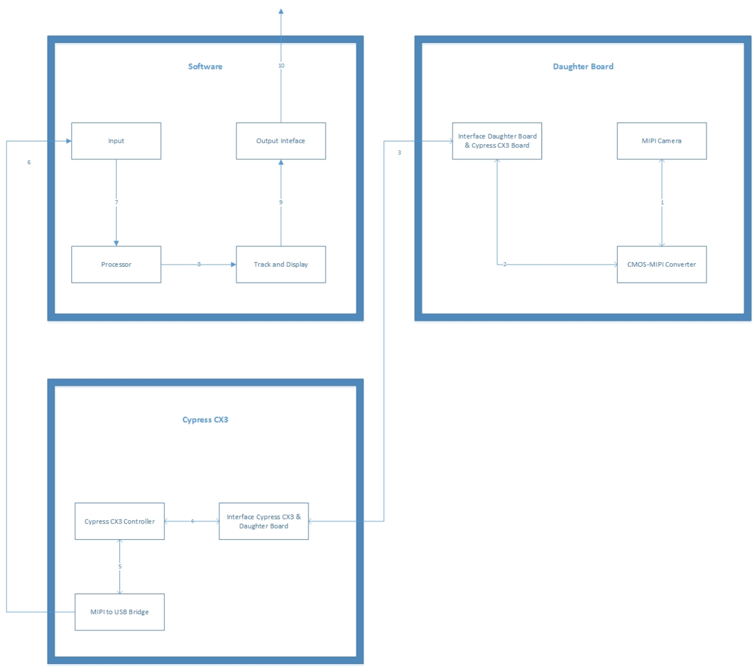

Figure 1: A simple architectural layer diagram

2.1 Software Layer Description

The software layer makes use of the OpenCV library and implements the entire program in C++ language. It consists of three major subsystems. The first subsystem is the Input subsystem. It gets input from the interface provided by the Jetson TK1. A video stream from a device (or a disk for test purposes) is read and stored into a CV::Mat structure. This structure will later be passed onto the processing subsystem. The goal of the processing subsystem is to filter out all the noise (anything but the pupil) and it does so utilizing readily available OpenCV algorithms which shall be discussed in detail later in the document. The final layer is the display layer which gathers information from the processor and displays the final result (fitted elipse) into the original video stream.

2.2 Daughter Board Description

The daughter board is a board that is used to interface between the camera module and the Jetson TK1. This board uses a high-speed rugged ground plane socket (Base BRD Connector) to transfer the data that the camera captures to the TK1. In order for the camera module (pcDuino Camera Module) to function properly the daughter board needed a new camera connector, since the original connector is not compatible. We replaced the old connector with the Panasonic connector (AXK824145WG). The purpose of the new camera connector is to interface the camera with the Base BRD Connector. The daughter board contains the OmniVision 5640 that is interfaced through the 2-lane MIPI interface.

2.3 Jetson TK1 Description

The Jetson TK1 is a MIPI to USB interface. This controller is fully functional with any image sensor that is compliant with a MIPI Camera Serial Interface (OmniVision 5640). The Jetson TK1 is used to control the communication between a computer and the device, since it uses a USB connection to power the device and transfer the data that it collected. Also in order for the device to store the data read from the camera module, it uses EEPROMS in order to prevent loosing data in cases the device looses power. Then the device will transfer its data to the computer via USB. The Jetson TK1 is also connected to the MIPI camera.

3 Subsystem Definitions & Data Flow

The following section shows a high level diagram of all layers of our system.

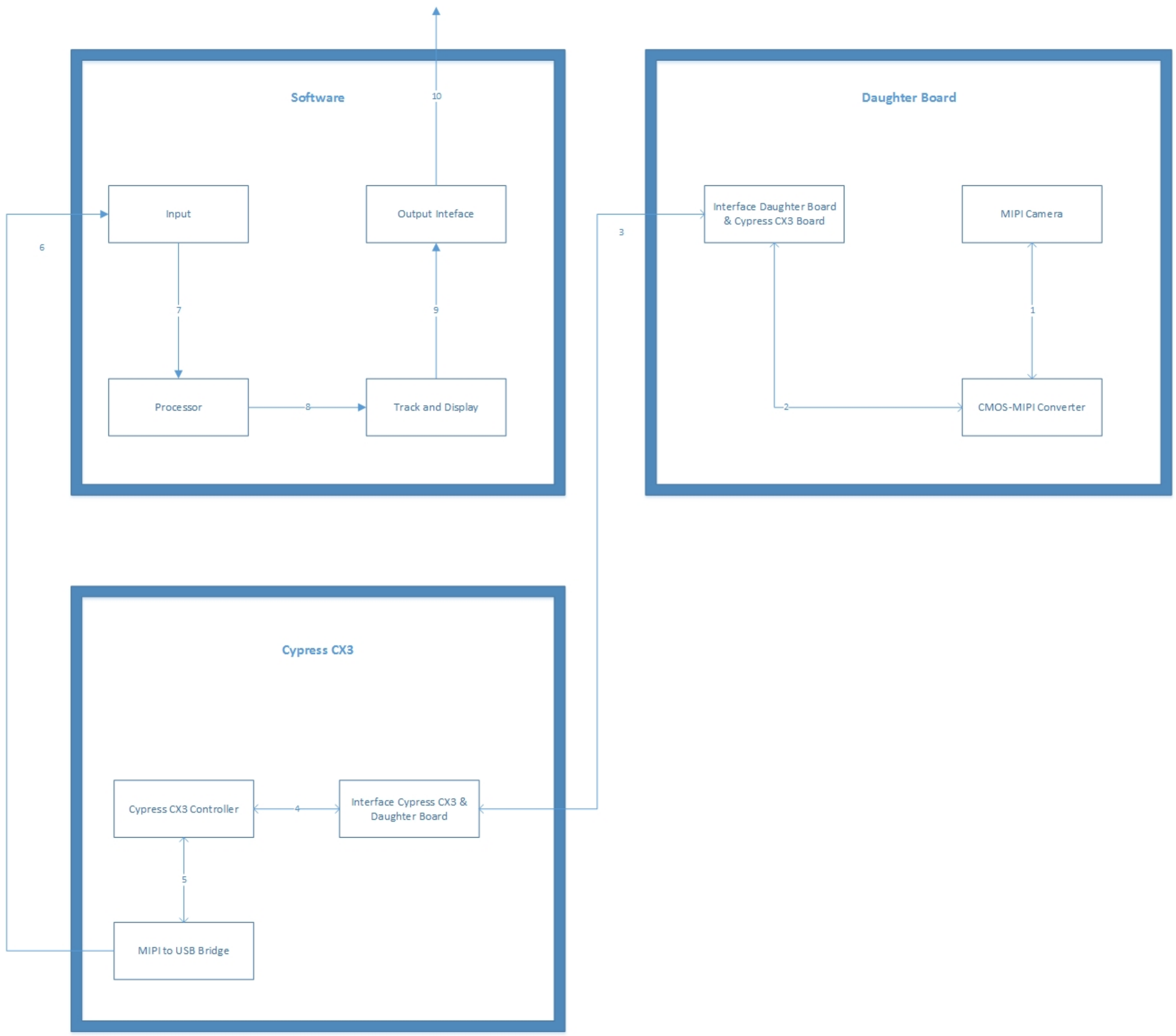

Figure 2: A simple data flow diagram

4 Software Subsystems

The Raspberry Pi 3 is a single-board computer that accepts MIPI cameras. This device will be used to connect an infrared MIPI Camera and stream a live video fee from the camera via ethernet. In order to avoid connectivity issues with the Jetson TK-1, the Raspberry Pi 3 has been configured with a static IP address. To assure that the live video fee has a small latency, the Raspberry Pi 3 will be connected to a router. The video feed is being streaming using VLC.

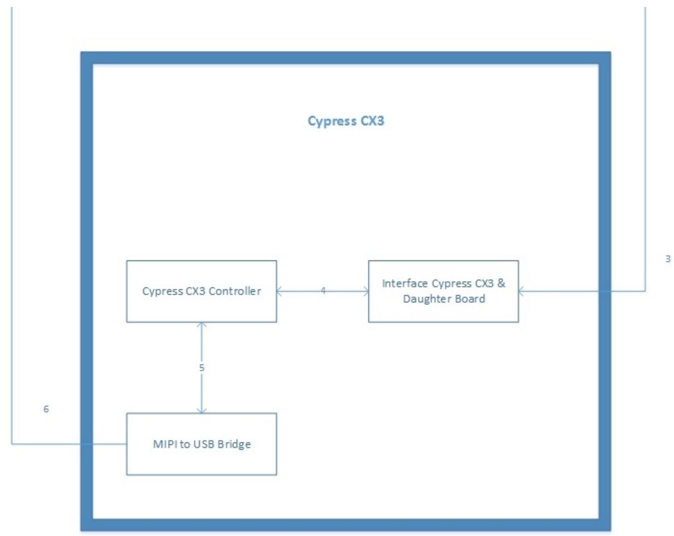

Figure 3: Jetson Subsystem Diagram

4.1 Central Processing Unit

The CPU of the Raspberry Pi is connected to multiple components. One of those components is the camera connector that needs to have a 15 pin ribbon cable in order to accurately receive a video feed from the MIPI camera. In this product, the camera connector is connected to an HDMI Extension Board via a ribbon cable. The CPU of this device also sends the live video fee using VLC via ethernet. All the user needs to have to capture the live video feed is the static IP address of the Raspberry Pi 3.

4.1.1 Assumptions

The user knows how to connect to the Raspberry Pi 3 via SSH using the Jetson TK-1 terminal.

4.1.2 Responsibilities

The responsibility of the Raspberry Pi 3 CPU is to start the live video stream.

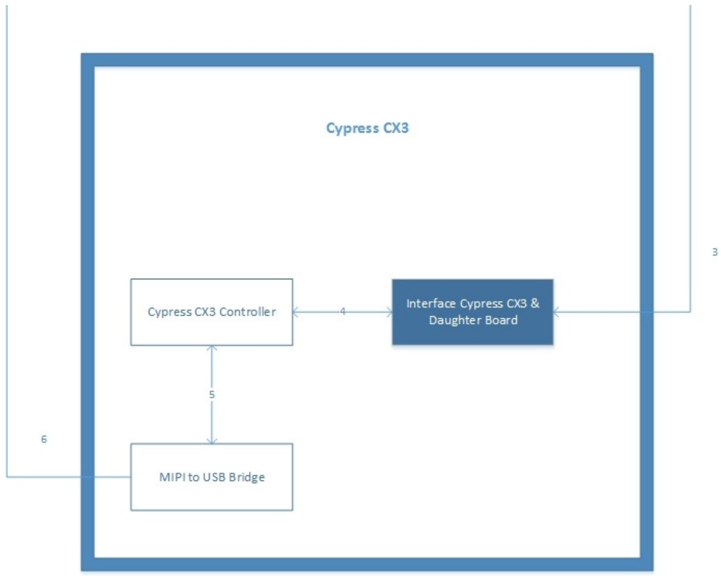

Figure 4: GPID Interface

4.1.3 Subsystem Interfaces

Table 2: Central Processing Unit

ID	Description	Inputs	Outputs
#01	HDMI Extension Board	Input 1 - MIPI Data	Output 1 - MIPI Power Output 2 - MIPI Clock
#02	Ethernet Connector	Input 1 - RX D2+ Input 2 - RX D2- Input 3 - BI D3+ Input 4 - BI D3- Input 5 - BI D4+ Input 6 - BI D4-	Output 1 - RX D2+ Output 2 - RX D2- Output 3 - BI D3+ Output 4 - BI D3- Output 5 - BI D4+ Output 6 - BI D4-

4.2 HDMI Extension Board

The sole purpose of the HDMI Extension Board is to give the user a longer distance between the MIPI camera and Raspberry Pi 3 in order to make the device more comfortable to the user. The HDMI Extension Board consists of two identical boards that are connected with an HDMI cable. One of the boards is connected via a ribbon cable to the Raspberry Pi 3 while the other board is connected to the Arducam Spy Camera for Raspberry Pi. The HDMI cable is used to send and receive data from and to the Raspberry Pi 3.

4.2.1 Assumptions

The HDMI cable connected between both boards is fully functional and compatible with both boards.

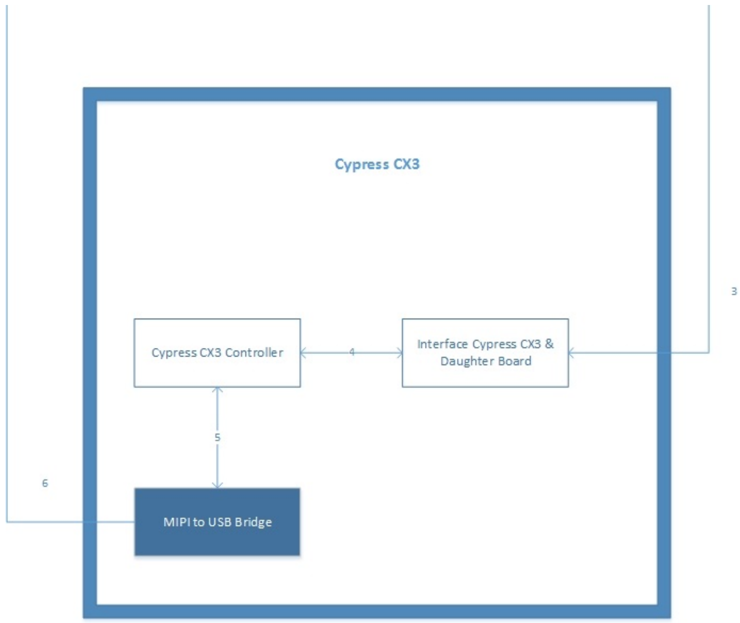

Figure 5: MIPI to USB Subsystem

4.2.2 Responsibilities

The HDMI Extension Boards are responsible with interfacing the infrared MIPI camera and the Raspberry Pi 3, and capture and sending a video feed.

4.2.3 Subsystem Interfaces

Table 3: HDMI Extension Board

ID	Description	Inputs	Outputs
#03	Board Connected To Raspberry Pi 3	Input 1 - 3.3V Input 2 - GND Input 3 - LVDS Data 0 to 1 +/- Input 4 - LVDS CLK +/-	Output 1 - 3.3V Output 2 - GND Output 3 - LVDS Data 0 to 1 +/- Output 4 - LVDS CLK +/-
#04	Both HDMI Extension Boards Connected Together	Input 1 - 3.3V Input 2 - GND Input 3 - LVDS Data 0 to 1 +/- Input 4 - LVDS CLK +/-	Output 1 - 3.3V Output 2 - GND Output 3 - LVDS Data 0 to 1 +/- Output 4 - LVDS CLK +/-
#05	HDMI Extension Board to MIPI Camera	Input 1 - MIPI Data 0 to 1 +/- Input 2 - MIPI CLK +/-	Output 1 - 3.3V Output 2 - GND Output 3 - LVDS Data 0 to 1 +/- Output 4 - LVDS CLK +/-

4.3 CMOS

The Arducam Sensor Spy Camera for Raspberry Pi has an Omnivision OV5647 sensor in which the CMOS memory chip is used to convert the data collected from the camera into RAW RGB that a computer can use to manipulate the data.

4.3.1 Assumptions

The CMOS sensor on the MIPI camera is fully functional and has not been damaged during the removal of the infrared filter.

4.3.2 Responsibilities

The CMOS sensor converts the images captured from the MIPI camera to a RAW RGB format that can be used by the software to track the user's eye.

4.3.3 Subsystem Interface

Table 4: CMOS Sensor OV5647

ID	Description	Inputs	Outputs
#06	CMOS to HDMI	Input 1 - CLK +/-	Output 1 - MIPI Data 0 to 1 +/-
#07	CMOS to MIPI	Input 1 - MIPI Data 0 to 1 +/-	Output - CLK +/-

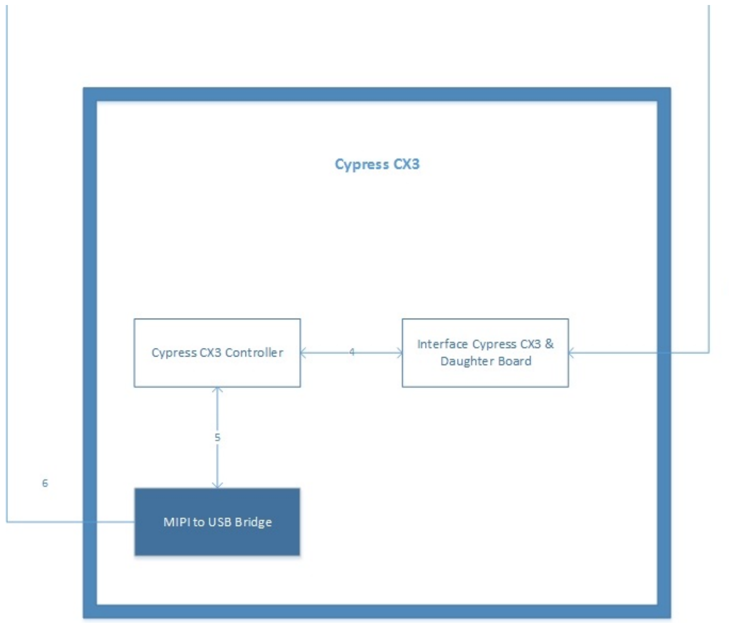

Figure 6: MIPI to CMOS Conversion & CMOS-HDMI Data Transfer

4.4 MIPI Camera

The Arducam Sensor Spy Camera for Raspberry Pi is the camera that has been selected to work on this project. Other cameras that are compatible with Raspberry Pi may also work on the eye tracker system. The only modification that needs to be made to this camera is to remove the infrared filter from the camera.

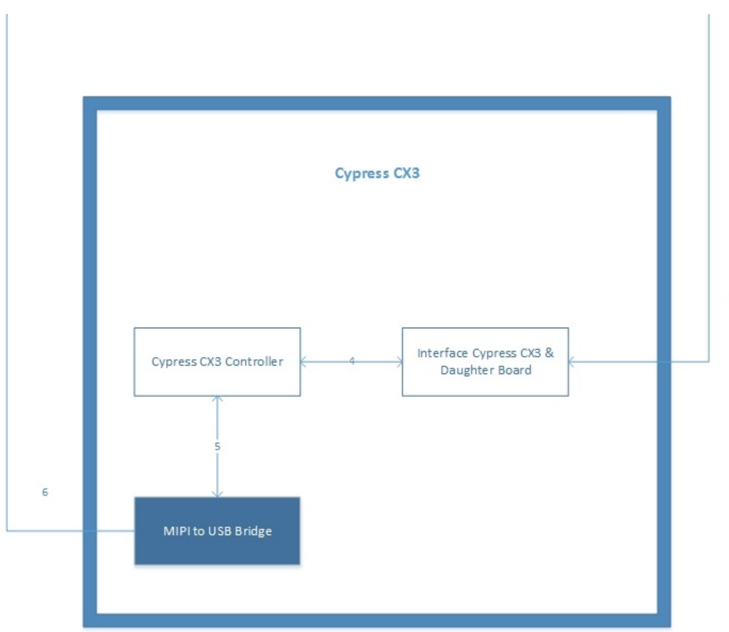

Figure 7: MIPI to HDMI Connection & MIPI to CMOS Connection

4.4.1 Assumptions

The camera used in the project is fully compatible with the Raspberry Pi 3, the camera has not been damaged during the infrared filter removal, and an infrared pass filter has been placed between the lens and the CMOS sensor.

4.4.2 Responsibilities

The responsibility of the MIPI Camera is to capture infrared video and send it to the Raspberry Pi in order to stream the video via ethernet.

Table 5: MIPI Infrared Camera

ID	Description	Inputs	Outputs
#08	MIPI to HDMI	Input 1 - 3.3V Input 2 - GND	
#09	MIPI to CMOS	Input 1 - MIPI Data 0 to 1 +/- Input 2 - MIPI CLK +/-	Output 1 - MIPI Data 0 to 1 +/-

5 Daughterboard Subsystems

6 Cypress CX3 Subsystems