Crowd Monitoring Device

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Contents

1 Introduction

1.1 Motivation

Computer vision is limited by a camera viewing objects from an angle, not top-down. Because of this, targets may overlap, preventing distinction. Spherical cameras are available for viewing nearby, cramped scenes, but they are expensive and not commercially available. They also require a heavy SW and mathematical effort to map a spherical projection to a plane. Faces and shapes of bodies, a big part of some computer vision, can get distorted.

We would like to create a modular tile to hook together on a ceiling and save researchers money they would have otherwise spent on chaining together Microsoft Kinects. Ideally we could provide information on human clusters moving through space and tell computer vision algorithms running on a professor's laptop where to look in his high definition camera's frame.

1.2 Objectives

We seek to make an array of sensors which will be directly above our targets. This way we can track motion across a space on a 1:1 scale without worrying about targets overlapping. This could be used in conjunction with installed computer vision to determine boundaries between people in a frame. We will group activated pixels into blobs to follow the trajectory of a human blob through space. Ideally we could incorporate data collected by our array processed with machine learning into computer vision.

By the end of the project, we want to accurately count the number of people passing a threshold. We want to accurately count the number of people within an area as long as we cover all entrances and exits.

2 Design

We seek to take an orthographic projection on a plane, detect whether distinct human figures are walking through the plane, and report this information to assist in other computer vision projects. Our design effort is comprehensive. At a broad scale, it covers signal processing, digital systems, circuit design, and machine learning. We see it as a refreshment for past coursework and a culmination of our undergraduate understanding of electrical engineering. As the reader will notice, evolution from our initial Piazza post and Request for Approval to our current project proposal is evidence of a continually evolving design process.

2.1 Block Diagram

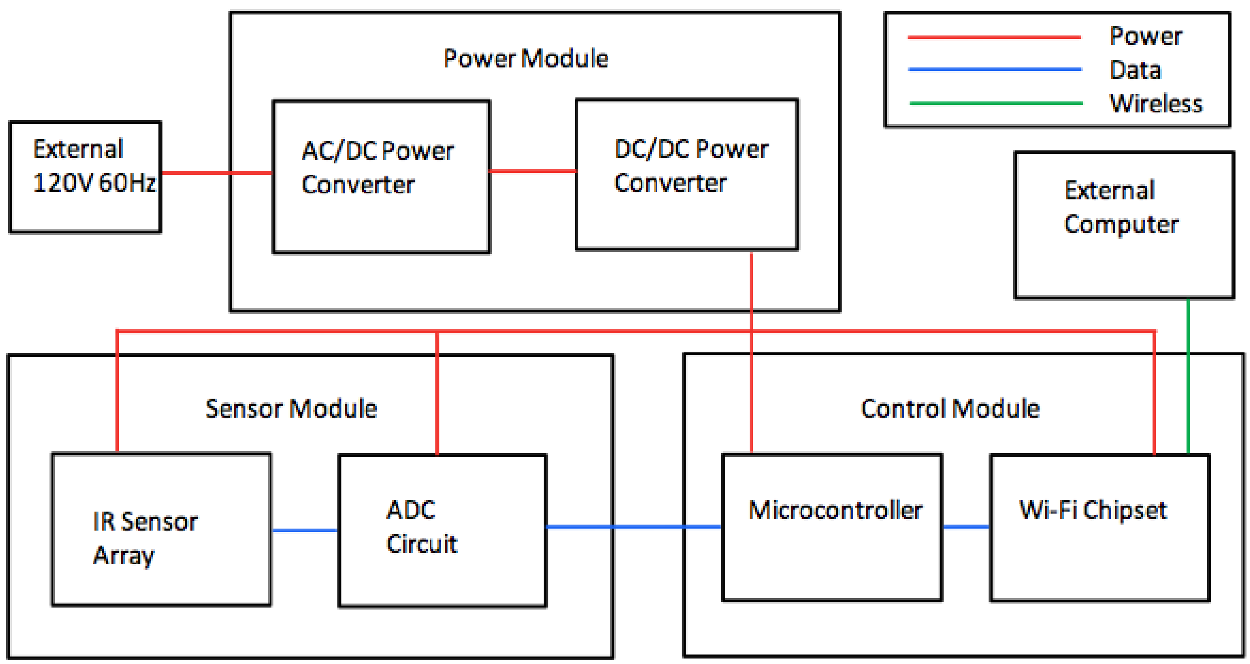

Figure 1: Block Diagram

2.2 Block Descriptions

2.2.1 Power Module

AC/DC Power Converter: This circuit will convert the standard 120Vac 60Hz signal to 12Vdc. Its purpose is to provide a DC voltage that can be easily manipulated by DC/DC power converter circuits.

DC/DC Power Converter: This circuit will convert the 12Vdc to various DC voltages to be used for the rest of the components in our project. Its purpose is to provide power to the rest of the components.

2.2.2 Sensor Module

IR Sensor Array: The sensor array will be 18 X 36 inches and will consist of 6 X 12 IR phototransistor layout spaced out by 3 inches. The individual IR phototransistors will have an IR absorbing cylinder to ensure only the IR light reflected directly underneath will be seen by the phototransistor. It will also contain IR LEDS for splashing the plane directly beneath the array.

ADC Circuit: The ADC circuit will first use an analog mux for each row which in turn will be muxed to select a column. This way every phototransistor is indexed. Each phototransistor circuit will amplify its signal so it can survive muxing. The output signal from the mux will be fed through an ADC so we can use the amplitude to determine certain height differences.

2.2.3 Control Module

Microcontroller: The microcontroller will use its clock to control the storing of each phototransistor's reading for a time slice. Then it will use a machine learning algorithm (DBSCAN, raster scan, or k-means) to identify clusters which identify a person. It will also transimt this data to the Wi-Fi chipset.

Wi-Fi Chipset: The Wi-Fi chipset will transmit the data received from the microcontroller to a central location. Since our device will be modular, you will be able to stitch the data received from multiple arrays to act as one larger array.

3 Requirement and Verification Table

Table 1: System Requirements and Verifications

Requirement	Verification
1. Module: IR Sensor Array (a) A human trips only a subset of the array. i. 12 sensors must trip to detect a body. ii. We want 6 sensors to trip for a head. (b) Tiles can be mounted to the ceiling. (c) A tile is 18 by 36 inches. Resolution is a sensor cell per 3 inches. Therefore, we have 6 by 12 sensors. (d) We switch IR sources at high frequency (choosing switching speed and duty cycle to create blip at 40 kHz on power spectrum) so, on reception, we can distinguish difference between ambient and artificial IR sources.	1. Module: IR Sensor Array (a) i. Average adult human body covers 18 by 10 inches. Take cardboard block of these dimensions, place under array randomly, and count pixels activated. ii. A human head covers 9 by 6 inches. Take cardboard block of these dimensions, place under array randomly, and count pixels activated. (b) Mount can support at least 5 pounds of force before failing. (c) Measure row and column spacing at perimeter with measuring tape. (d) Tap voltage across IR source with oscilloscope, FFT on oscilloscope reveals power near 40 kHz.

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Table 1 – continued from previous page

Requirement	Verification
2. Submodule: IR Sensor Cell (a) IR Sensor Cell can read dynamic range between 0 and 5V with step of millivolts. i. Sensor should operate in ambient IR condition of an indoor location without saturating. ii. Assuming sensors do not saturate, normalize readings so ambient conditions are not causing activations. (b) IR Sensor Cell can only sense for one pixel. i. An IR beam is received at 1.455 degree effective angle. We assume 3 meters between array and ground, with 3 inch (.0762 meter) sensor spacing. Angle may change depending on height of tile from ground. Use arctan(.0762 meters/meters to ground) for correct angle. ii. IR Sensor Cell should only detect motion within 3 by 3 inch area. iii. Tube in IR Sensor Cell for focusing received IR beam should have IR black material. (c) Source shoots proper intensity beam s.t. power density reflections on receiver is between 0 and 5 mW/cm^2.	2. Submodule: IR Sensor Cell (a) i. Place sensor array in various rooms and verify that any one IR sensor is not outputting max voltage/current. We don't want clipping. ii. Place the array in various rooms, detect whether ambient IR is uniform with FLIR camera, introduce ambient IR uniformly on the array, and see no activations when object is not below array. (b) i. Shoot IR beam from greater than 1.455 degrees (or arctan(.0762m/m to ground)) at receiver cell and we should see less than 10% change in current/voltage. ii. Mark 3 by 3 inch pixel area on floor directly below IR Sensor Cell and motion outside square. Sensor Cell should not show activation. iii. Shine IR light at tube material and receive little reflection (less than 10% transmitted signal). (c) Trigger IR source to reflect off the ground, off hair, off cloth. Measure power dissipation at receiver with oscilloscope, divide by 36 mm^2 (approximate size of receiver).
3. Submodule: ADC Circuit (a) Each pixel can be indexed by a mux. (b) We must amplify voltages at pixels to get signal through muxes and quantifiable by ADC. (c) We must sample array data (muxing, ADC, capture by microcontroller) on the order of MHz.	3. Submodule: ADC Circuit (a) For one row in IR receiver array, shine IR source on each individual receiver, index this with mux structure. Does value change when you turn source on and off? (b) Measure voltage at output of mux when indexing illuminated IR receiver. With saturation of receiver, output of mux still reads within millivolts of 5V. (c) Time full sampling of array (mux, ADC, storage in microcontroller memory).

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Requirement	Verification
3. Module: Control Unit (a) Microcontroller provides signals for triggering IR sources, clocking and coonfiguring ADC, indexing array muxes, sampling sensor array. (b) Microcontroller needs to read samples from ADC. (c) Microcontroller needs to identify clusters of pixels through machine learning. (d) WiFi chip needs to send/receive cluster data to and from central server.	3. Module: Control Unit (a) Write a testbench with all control signals and view waveforms. (b) For 1 second, illuminate IR array and initiate sampling. Check that micrcontroller memory is populated with new readings. (c) With entire system running, walk through sensor array. One human should be determined. (d) Connect WiFi chip to central server. Send test byte back and forth.
4. Module: Power Module (a) DC/DC power converter circuits take input of 12Vdc and provide various outputs (5Vdc 2A, 5Vdc 1mA, 1.4Vdc 50mA, 3.6Vdc 0.39mA) (b) AC/DC power converter circuit takes input of 120Vac 60Hz and provides 12Vdc at rated power of entire product	4. Module: Power Module (a) Apply 12Vdc to input, place load resistor at each output, use a multimeter and ammeter to measure the voltage drops across the load and current drawn (b) Apply 120Vac 60Hz to input, place load resistor at each output, use a multimeter and ammeter to measure the voltage drops across the load and current drawn

4 Tolerance Analysis

We believe the most important part of our system is the normalization of the IR phototransistor readings and making sure we don't operate the panel in an environment flooded with IR. Ambient conditions could cause erroneous activations and therefore the data we process could produce false positives. Ambient conditons with high intensity IR could saturate our sensors. The phototransistor detects irradiance between $0 - 5mW/cm^2$ and it needs to have a dynamic range to differentiate between someone's head and shoulders.

To make sure we keep a dynamic range in an average, nonflooded environment, we will normalize the ambient IR readings in software.

Once we are able to gather data on how much the source IR light attenuates after reflection from shoulder height and head height, we will be able to provide specific tolerances for source intensity.

5 Cost and Schedule

5.1 Cost Analysis

5.1.1 Labor

Table 2: Labor Costs

Name	Hours Invested	Hourly Rate ($)	Total * 2.5 Engineering Factor ($)
Armando Juresic	250	34.00	21,250.00
William Schellhorn	250	34.00	21,250.00
Total	**500**	**68.00**	**42,500.00**

5.1.2 Parts

Table 3: Parts Costs

Part	Manufacturer	Retail Cost ($)	Bulk Purchase Cost ($)	Actual Cost ($)
LTR-3208E Infrared Phototransistor	LITE-ON	1 @ 0.70	100 @ 0.40	40.00
Microcontroller		max 5.00		max 5.00
BL-L513IRAB IR LED	BetLux Electronics	1 @ 0.39	100 @ 0.15	15.00
CD74HC4067SM96 16:1 Analog Mux	T.I.	1 @ 0.85	10 @ 0.75	7.50
ADS7868IDBVR ADC	T.I.	1 @ 1.68	10 @ 1.51	1.68
ESP8266 Wi-Fi	ESPRESSIF	1 @ 6.95	100 @ 6.26	6.95
Total				**76.13**

5.1.3 Grand Total

Table 4: Project Total

Labor Cost ($)	Parts Cost ($)	Grand Total ($)
42,500.00	76.13	42,576.13

5.2 Schedule

Table 5: Schedule

Week	William	Armando
09/18/2016	Simulate movement through a grid using python.	Draft AC/DC, DC/DC power conversion and ADC circuits.
09/25/2016	Design IR Sensor Cell, surrounding circuit, and muxing	Design FSM for Control Unit
10/02/2016	Write machine learning algorithm	Build Sensor Cell prototype
10/09/2016	Prototype array	Program control module with FSM, interact with WiFi chip
10/16/2016	PCB layout	Continue prototyping sensor module
10/23/2016	Write code for central server stitchin	Assemble first array with power module
10/30/2016	Assemble second array with power module	Revise PCB layout if needed
11/06/2016	Testing and Debugging	Testing and Debugging
11/13/2016	Testing and Debugging	Testing and Debugging
11/20/2016	Thanksgiving Break / Testing and Debugging	Thanksgiving Break / Testing and Debugging
11/27/2016	Demo	Demo
12/04/2016	Presentation	Presentation