Self Adjusting Rear View Mirror

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1 Introduction

1.1 Objective

The auto industry spends billions of dollars each year developing safer technology for cars. Despite this, rear view mirrors have remained relatively unchanged throughout the last century. We propose designing a rear view mirror that can track the driver's eye position, and adjust the mirror's orientation such that the driver retains perfect view of the rear window. We propose using a three axis robotic arm to position the mirror, so that the mirror can achieve the desired pitch, roll, and yaw. We will also be using an infrared camera in conjunction with infrared LEDs to capture images of the cabin. A neural network running on a CPU will be used to identify the position of the driver's eyes.

1.2 Background

Automotive accidents result in up to 1.3 million deaths and 50 million injuries per year[1]. If even a small fraction of these accidents could have been prevented with a properly adjusted rear view mirror, thousands of lives, and potentially millions of dollars, would be saved. When driving over long trips, drivers tend to periodically adjust their positions. If a driver's height is adjusted only a few inches, a majority of the rear window can become obscured from view in the rear view mirror. In order to fix this, driver's must take their eyes off the road, and a hand off the wheel, to readjust the mirror. As there is estimated to be over 1 billion drivers on earth[2], each driving thousands of miles a year[3], these minutes of driving with obstructed rear windows and adjusting mirrors adds up to a serious safety concern. A self adjusting rear view mirror could reduce distractions and improve vision for drivers globally.

1.2 High Level Requirements

1) Rearview mirror must display a clear, centered image through the view of the rearview window. Ideal alignment should place the center of the rearview window at the center of the rearview mirror. The mirror control system should calculate the anglings required for this ideal alignment to within 3 degrees of accuracy, and mirror hardware should be positioned to within 3 degrees of the calculated alignment, after calibration.

2) During normal operation, mirror shall require no input from user. The mirror shall require zero corrections or prompts from user once the mirror has been set up for use, for the duration of operation.

2 Design

Our project requires 3 components to achieve the high level requirements: power, control, and hardware. The block diagram below (figure 1) shows how the three components will interact. A car battery will provide power for the project; we will implement hardware to regulate the power for the hardware and control components. The hardware includes the motors for orienting the mirror, the camera and LEDs for taking images of the cabin, and components that allow the user the control the mirror. The control component consists of a CPU (to process the images and set the desired joint angles accordingly), and an analog control circuit for motor 3 (the motor controlling roll). To accomplish correct orientation of the mirror to within 3 degrees (as listed in the high level requirements), we intend to use servos for motors 1 and 2. This should provide us with correct orientation within about one degree. By calibrating the camera to find a mapping between pixel location and angle from camera, we can identify the angle from the normal vector of the mirror to the user's eyes to within 3 degrees. As we will have feedback for all three joints, there should be no need to manually correct the orientation of the mirror. If any joint is improperly orientated, the control system should automatically compensate, thus satisfying the other high level requirement.

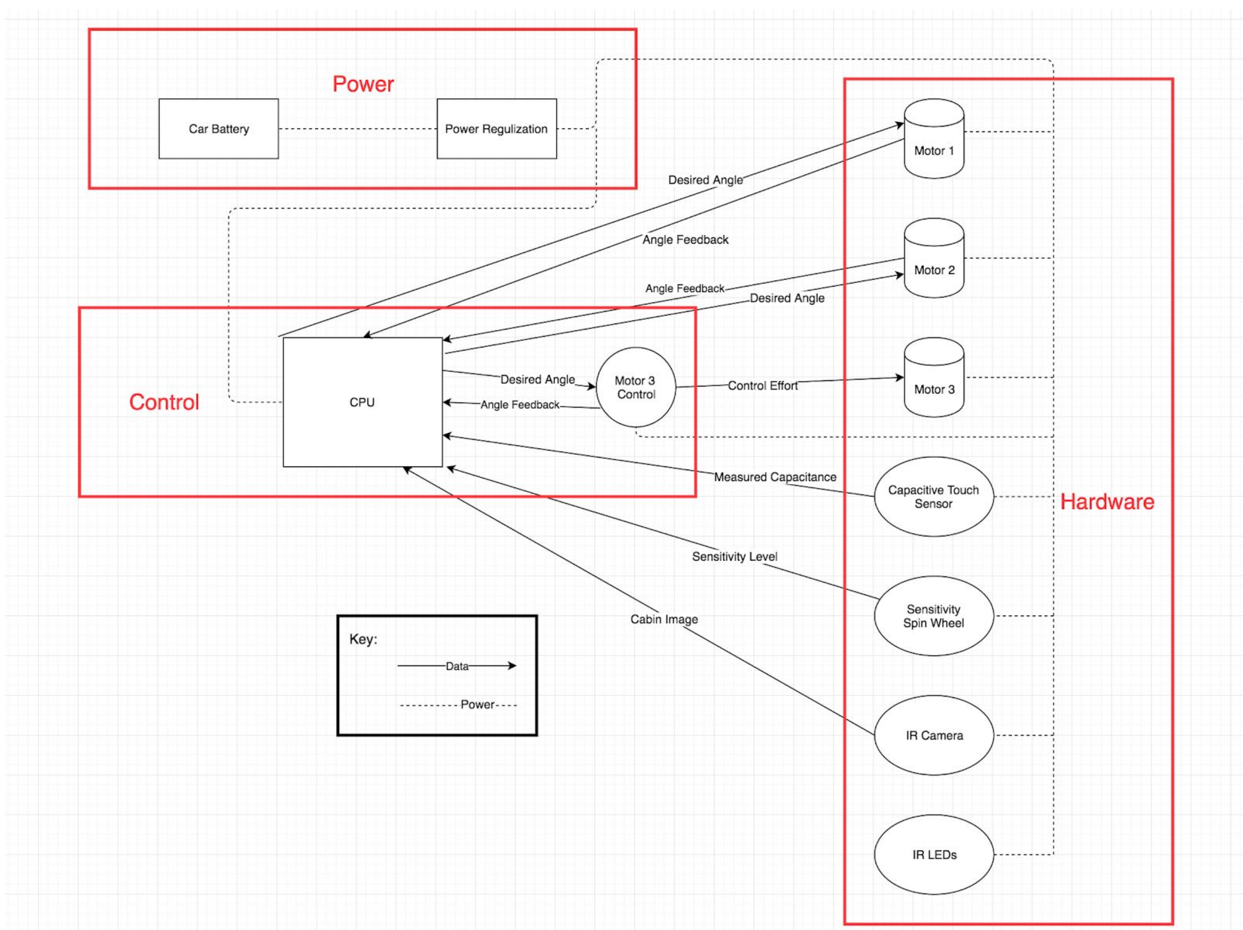

Figure 1: Block Diagram

2.1 Power

2.1.1 Car Battery

The car battery will be the power source of our entire project. The car battery will provide roughly 12 volts, which will be converted to the desired voltages via DC to DC converters. As car batteries are capable of providing hundreds of amps, this power source should be able to provide more than enough power for our project.

Requirements: The car battery must be capable of providing 11-13 volts, and at least 5 amps of current.

2.1.2 Power Regulator

Primary power will be provided by a 12V car battery. This voltage must be stepped down in order to power the servos, motor, IR devices, and control hardware. This functional block will step down power to values which are usable by the rest of the hardware.

Requirements: Primary power will be provided by a 12V car battery. These generally have a voltage range of 12.6V to 11.4V. This will need to be stepped down to about 6V (5.0V to 8.4V) for the servos, and roughly 3.3V (3.0 to 3.6) for the IR camera and control hardware. Maximum power draw will be on the order of several amps (1200 mA stall torque on servos, with additional draw from DC motor, camera, LEDs, etc).

2.2 Control

2.2.1 CPU

The CPU will control the image processing from the IR camera as well as reading the inputs from the motors and user IO devices. The CPU will be running software to classify the location of the eyes. The CPU will then compute the mapping from pixel location to angle from principal axis of the camera, and send signals to adjust the joints accordingly.

Requirements: The CPU will not draw more than 5mA of current during operation. The CPU will operate at voltages no lower than 2V and no higher than 5.5V. The CPU will operate at a frequency no slower than 1MHz.

2.2.2 Motor 3 Control

This will be an analog control circuit for the third motor (which will be a DC brushless motor), and will be used in controlling the roll of the mirror. The CPU provides the desired angle into the control circuit; the circuit than adjusted the motor to the desired angle. A potentiometer or rotary encoder will be used as feedback for the control system.

Requirements: The controls for the third motor must be configured such that the system can be controlled to within 1 degree. Operating voltages can be as high as 6 volts.

2.3 Hardware

2.3.1 Motor 1

Motor 1 will orientate the yaw of the mirror, providing the first degree of freedom for the mirror. The motor will receive power from the power regulator, and a control signal from the CPU. As the yaw must be accurate to a high resolution, a servo motor will be used. This motor will support the weight of the mirror, camera, and other two motors whilst rotating.

Requirements: Motor 1 must have a maximum continuous stall torque greater than 1 kg-cm. The motor must have angle feedback accurate to within 1 degree. The motor must weight less than 100 g, and must have all dimensions less than 3 inches.

2.3.2 Motor 2

Motor 2 will orient the pitch of the mirror, providing the second degree of freedom for the mirror. The motor will receive power from the power regulator, and a control signal from the CPU. As the pitch must be accurate to a high resolution, a servo motor will likely be used. This motor will support the weight of the mirror, camera, and the third motor whilst rotating.

Requirements: Motor 2 must have a maximum continuous stall torque greater than 1 kg-cm. The motor must have angle feedback accurate to within 1 degree. The motor must weight less than 100 g, and must have all dimensions less than 3 inches.

2.3.2 Motor 3

This motor shall provide roll control for the mirror, providing the 3rd axis of movement for the mirror. For roll, only a small motor is required due to the expected position ranges, facilitating the use of a small DC hobby motor. This also conserves space and saves weight, reducing the load placed on the two servos.

Requirements: Must have range of movement of at least 7 degrees. With proper position measurement (potentiometer), less than 3 degrees of accuracy is feasible. Accuracy of the roll position would be dependent on outside hardware.

2.3.3 Capacitive Touch Sensor

As every car is different, the correct angling of the mirror in one car may be incorrect in another. To allow our mirror to work for all cars, we have the user set the desired angle once so that the mirror can track that spot. Since it is not easy to grab and move servo motors to a desired location, we must have a way to identify that the user is trying to adjust the orientation of the mirror, and allow this adjustment to occur. By adding capacitive touch the the exterior rim of the mirror, it can be identified that the user is adjusting the mirrors. Once this is identified, feedback can be used to determine the direction of adjustment. The capacitive touch sensor will be powered by the voltage regulator, and will input into the CPU whether or not the user is attempting to adjust the mirror manually.

Requirements: The Capacitive touch sensor must detect touch when touched using a force greater than one Newton, with skin (i.e. gloveless) contact.

2.3.4 Infrared Camera

The IR camera will collect visual information in order to track the user's eyes. IR is more reliable during expected driving conditions, and offers the possibility of hiding the sensor from view, by placing the camera behind the mirror. Placing the camera behind the mirror simplifies the task of controlling the mirror, and eliminates the need for a second camera.

Requirements: The IR camera shall provide an HD image (better than 1280X720) resolution in support of eye-tracking. Visible light varies between 100,000 lux during daytime and .0001 lux during nighttime. By using IR in conjunction with IR illumination, the IR camera shall maintain sufficient image quality to facilitate consistent eye-tracking. The camera shall require less than 1W of power, operating in the range of 3.0-3.6V with a current draw of no more than 250mA.

2.3.5 Infrared LED

The IR LEDs will be used to illuminate the cabin to get a clear image of the driver's face. It is necessary to use IR because it is not visible to the human eye and as such will not interfere with the driver during operation of the vehicle.

Requirements: The LEDs will need to be chosen in a manner such that the wavelength emitted does not get absorbed by the material chosen to use in the mirror, however the wavelength must be large enough that the driver is unable to see the light during operation. Operating voltage can be as high as 6V. Current draw must be less than 1A for the entire array of IR LEDs.

2.3.6 Sensitivity I/O

The sensitivity i/o will be the user's means of setting the "tracking sensitivity" of the mirror. It may not be desirable for the mirror to adjust to the user's every movement (like when the driving is checking his blind spot). If the mirror is tracking at a rate which is either too aggressively or too passively, the user can adjust the tracking with the sensitivity i/o, which will likely be some sort of spin wheel. The sensitivity i/o will receive power from the power regulator, and output the desired sensitivity to the CPU.

Requirements: The sensitivity spin wheel must rotate at least 180 degrees and be smaller than 2 inches in diameter.

2.4 Risk Analysis

The most pivotal component in this project will be the software running on the CPU. Since most, if not all, the control logic and image processing will be in software, it is crucial for the software to work flawlessly. If the software is even slightly erroneous, there could be fatal consequences for anyone who tries to use this product.

3 Ethics and Safety

There are no apparent ethical concerns in this project. While there is a camera pointing at the driver at all times, the data is only transient and will not exist once the computations have been completed. In addition, the system is not connected to any networks, so there is no way for any external parties to access the video stream.

The control system presents the greatest risk to the project, due to the number of unknowns and the required precision of the system. With a well-functioning camera system and properly functioning servos, the hardware of the system should be fully capable of responding to the positioning information from the control system. However, if the control system cannot provide sufficiently accurate control information, the system will not provide the desired experience to the user. Variables such as lighting, quality of the eye-tracking, excessive vibration or movement, etc. all risk degrading the experience of the final product.

Additionally, there may be unknown problems caused by quirks in human perception or the operation of the hardware and control system. If movement is jittery, too frequent, or too infrequent, the mirror may be uncomfortable to use, or may not function as well as a traditional mirror.

References

[1] *Youth Road Safety Education - ASIRT*. www.asirt.org/Initiatives/Informing-Road-Users/Resources-Publications/Youth-Road-Safety-Education.

[2] Voelcker, John. “1.2 Billion Vehicles On World's Roads Now, 2 Billion By 2035: Report.” *Green Car Reports*, 29 July 2014, www.greencarreports.com/news/1093560_1-2-billion-vehicles-on-worlds-roads-now-2-billion-by-2035-report.

[3] DiLallo, Matthew. “The Average American Drives This Much Each Year -- How Do You Compare?” *The Motley Fool*, The Motley Fool, 25 Jan. 2015, www.fool.com/investing/general/2015/01/25/the-average-american-drives-this-much-each-year-ho.aspx.