Self Adjusting Rear View Mirror

ECE 445 Design Document
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Group 22
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10/1/18
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. Recent technical improvements offer increased visibility and safety, but come with a high price tag[1], and provides a far different experience than the traditional rearview mirror[2]. These designs use a rear-facing camera to turn the rearview mirror into a display. We instead propose designing a rear view mirror that can track the driver’s eye position, and mechanically adjust its orientation such that the driver retains perfect view of the rear window.

Such a mirror would function as a regular mirror would, with the added benefit of maintaining visibility without user adjustment. Such a system would be cheaper than the current state-of-the-art, and would provide users with the comforting familiarity of traditional rearview mirrors. Our system would use a three axis robotic arm to position a reflective mirror, so that the mirror can achieve the desired pitch, roll, and yaw. We will then be using an infrared camera in conjunction with infrared LEDs to capture images of the cabin, and a neural network running on a CPU will be used to identify the position of the driver’s eyes. The mirror will use this information to adjust itself so that the user retains visibility through the rearview mirror as the user shifts position.

1.2 Background

Automotive accidents result in up to 1.3 million deaths and 50 million injuries per year[4]. 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[5], each driving thousands of miles a year[6], these minutes of driving with obstructed rear windows and adjusting mirrors adds up to a serious safety concern.

Some carmakers have integrated displays into their rearview mirrors, fed by a wide-angle rear facing camera[1]. This setup improves visibility by displaying an image from outside the car- only an obstruction between the driver and the mirror, or something blocking the view of the external camera, would impede driver visibility. Regardless of orientation, the same image, fed from the external camera, is displayed on the mirror. A user can shift around the cabin without losing rearward visibility. Much like a backup camera, such a setup improves field of view, giving the driver more information about their surroundings. However, the driver cannot use such a display to look at the back seat, or use their vehicle as a point of reference for traffic behind them.
Obstructions such as trailers or tall vehicles may block the view of the camera, whereas a traditional mirror may not be obstructed.

Drivers may feel uncomfortable adjusting to a new setup, after years or decades of using a traditional mirror. The enhanced field of view may feel like a distraction or nuisance to drivers (regardless of the advantages). Regardless of how much of an improvement such a setup is, people will need to feel comfortable using the technology to realize any benefit from it. A self-adjusting rear view mirror offers up some of the advantages of these electronic rearview mirrors, without changing the experience of a traditional mirror. Users would still benefit from the increased visibility and hands-free nature of the technology. While it could be argued that drivers should instead be educated on how to use the new electronic display rearview mirrors, it could also be argued that the heavily prevalent blind-spot monitoring technology is just as unnecessary, and that drivers should instead be educated on how to properly adjust their side view mirrors[3]. Regardless of performance, the cost advantages of our design provides enough reason to develop our proposed system.

1.3 High Level Requirements

1. Rearview mirror must achieve an orientation within 3 degrees of the user's desired orientation.

2. The part cost for the mirror shall not exceed $150.

3. The mirror must not oscillate whilst the user remains in the same location.

2 Design

2.1 Block Diagram

Our project requires three components to achieve the high level requirements: Sensors and I/O, Motor Control, and Power Supply. The block diagram below (figure 1) shows how the three components will interact. A car battery will provide power for the project; we will design hardware to regulate the voltage to 3.3V for the sensors and motor control, as well as a separate regulator circuit for the stepper motors. The sensors include the camera and LEDs for taking images of the cabin, limit switches for determining the absolute orientation of the three motors, and a calibration button to allow the user to set the desired direction for the mirror to track. The motor control component consists of a CPU (to process images and set the desired joint angles accordingly), stepper motor drivers, and the stepper motors. Since the stepper motors have a step size of 0.9°, the motors should have high enough resolution to achieve desired orientation to within 3°. As the motors are stepper motors, the angles of the motors are discrete. This means that if the user is not changing position, if the desired orientation is achieved, the mirror shall not oscillate.
2.2 Physical Design

The mirror mount design takes inspiration from 3-axis camera gimbals, giving 3 degrees of freedom (roll, pitch, and yaw). This design greatly simplifies the control logic and required hardware, by placing the camera at the center of rotation for all 3 axes. By having the mount rotate around the camera, the camera remains fixed in place. With this, any relative motion between the camera and user can be attributed to the user’s movements. Additionally, placing the camera in the center of the mirror means the user will effectively be looking into the camera. The control system will not need to know the user’s distance, and calculations may instead be performed using angles of rotation, rather than 3-dimensional coordinates.
2.3 Block Design

2.3.1 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.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car battery outputs 11-13 volts</td>
<td>A. Measure open circuit voltage using voltmeter</td>
</tr>
<tr>
<td></td>
<td>B. Ensure voltage is within 11V to 13V range</td>
</tr>
<tr>
<td></td>
<td>C. Charge battery and repeat verification if voltage is out of range</td>
</tr>
</tbody>
</table>

2.3.2 Voltage Regulator

Primary power will be provided by a 12V car battery. This voltage must be stepped down to 3.0V to 3.6V in order to power the stepper motors, IR devices, and control hardware. This functional block will step down power to values which are usable by the rest of the hardware.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output voltage is between 3.0V and 3.6V during operation</td>
<td>A. Stall at least 1 motor while hardware is operational</td>
</tr>
</tbody>
</table>
### 2.3.3 CPU

The CPU will control the image processing from the IR camera as well as reading the inputs from 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 stepper motors accordingly. For responsiveness, the CPU must have enough processing power to process 1 image per second for eye tracking, in addition to handling motor control.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Return eye tracking information from 1 image per second</td>
<td>A. Provide CPU with 1 image per second&lt;br&gt;B. Verify CPU computes eye location information for each image</td>
</tr>
<tr>
<td>2. Provide motor control commands while operational</td>
<td>A. Verify CPU also outputs motor control commands when appropriate</td>
</tr>
</tbody>
</table>

### 2.3.4 Motor Controller

The motor control circuit will control the stepping action of the stepper motors. The circuit will be taking input from the CPU and will be sending pulses to the stepper motors appropriately.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
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<tbody>
<tr>
<td>1. Circuit must provide ample power to the motors in high torque scenarios i.e. when at least 1 motor is stalled</td>
<td>A. Send constant driving pulses to the motor while preventing motor from stepping&lt;br&gt;B. Verify motor does not move and circuit does not fry in demanding circumstances</td>
</tr>
<tr>
<td>2. Circuit must send out appropriate pulses from CPU input</td>
<td>A. Configure CPU to send pulses to the control circuit&lt;br&gt;B. Verify that motors move upon receiving signal</td>
</tr>
<tr>
<td>3. Circuit must send out pulses capable of turning the motors by one step (0.9 degrees)</td>
<td>A. Configure CPU to send out exactly 400 pulses</td>
</tr>
</tbody>
</table>
2.3.5 Motor 1-3

Motor 1, Motor 2, and motor 3 will orientate the yaw, roll, and pitch of the mirror, respectively. The motors will receive power from the voltage regulator, and a control signal from the motor control. The motors will be two phase stepper motors.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
</table>
| Motors shall be capable of rotating the mirror without stalling | A. Command mirror to tilt right  
B. Verify mirror shifts right without stalling |

2.3.6 IR Camera

The IR camera will collect visual information to track the user’s eyes. IR is more reliable than visible light during expected driving conditions, such as low-light. Placing the camera behind the mirror simplifies the task of controlling the mirror and eliminates the need for a second camera. By using the IR camera in conjunction with IR illumination, the IR camera shall maintain sufficient image quality to facilitate consistent eye-tracking.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
</table>
| Eyes shall be visible in IR camera images when placed 3 feet from a person’s face | A. Position camera 3 feet away from subject  
B. Take image of subject  
C. Verify image provides clear picture of subject’s eyes |

2.3.7 IR LED

The IR LEDs will be used to illuminate the cabin to get a clear image of the driver’s face. IR was selected because it is not visible to the human eye and as such will not interfere with the driver during operation of the vehicle. While driving at night, through tunnels, under bridges, or through shade, the IR LEDs can provide a consistent level of illumination for the camera. This illumination should be sufficient for the camera to operate but should not draw an excessive amount of power.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
</table>
| Current draw must be less than 2.5A for the entire array of IR LEDs. | A. Power LED array  
B. Measure current using an ammeter  
C. Verify total current draw is less than 2.5A |
2.3.8 Calibration button
Using a button located on the mirror mount, the user will be able to set their mirror preferences prior to operation. The mirror will maintain the orientation set by the user during operation, tracking the user.

2.3.9 Mirror Mount
The mount must be robust enough to carry the weight of the motors, LEDs, and camera. Our chosen motors do not have a listed weight; however it is expected that each motor and set of motor hardware will weigh less than 1 pound. Mount materials and mirror are expected to weigh under 1.5 pounds. The additional mounting hardware will weigh in at under 0.5 pounds. The weight of the electronics is expected to weigh less than 1 pound. Total weight is estimated at under 6 pounds.

It must also withstand the force the user will apply to the mirror in order to adjust initial orientation, as well as any vibrations caused by the mirror’s environment or operation of the motor. The mount will be fabricated from a durable plastic using a 3-D printer.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mount must be capable of holding all components (less than 6 pounds)</td>
<td>1. A. Populate mount with either all necessary hardware, or 6 pounds of weight. B. Verify mount does not fall apart</td>
</tr>
<tr>
<td>2. Verify mount can be adjusted without breaking</td>
<td>2. A. Take completed mount B. Adjust mount C. Verify mount does not fall apart</td>
</tr>
</tbody>
</table>

2.4 Software
Per the block diagram, the camera will provide visual information to the CPU, at which point the CPU will extract eye-tracking information used to command the motors. After the user sets their desired initial position, the system will compensate for changes in the user’s position.

To achieve a mapping between camera pixel location and angle from normal vector of the mirror, the following algorithm can be used:
// Initialization
Set all motor angles to 0
Position LED such that it is in the center of the camera’s image

For each step in yaw motor:
  For each step in pitch motor:
    Take image
    Identify location of LED in image
    Map pixel location of LED to pitch and yaw in a dictionary

Note that this process should be done in a dark room to prevent interference from other light sources. After this process is completed, we will have a discrete mapping from pixel location to angle from normal vector. When using this mapping in practice, the user’s eye location will almost never be in the exact pixel location that has an entry in this dictionary. While we will have to round to the nearest pixel, as each step size is 0.9°, the resulting inaccuracy should be within our limit of 3°.

While operating, the software has two significant states: tracking and calibration (see figure 3). During tracking, the mirror is processing images to determine if the desired orientation of the mirror should change, and if the actual orientation of the mirror should change. During calibration, the software processes images to determine the new “tracking frame” when prompted by the user.
2.5 Equations

Let us define a base reference frame for the robotic arm of our mirror. This frame, O₀, will be the center of the rear-view mirror. The X axis of O₀ is normal to the mirror when all joint angles are zero. The Z axis of this frame is directly upwards. We can compute the forward kinematics of the rear-view mirror to parameterize the orientation of the mirror as a function of the joint angles.

The mirror rotates around the Z axis of O₀. The transformation of this rotation is represented by Equation 1. The frame that results from this transformation is O¹. Similarly, Equation 2 represents the mirror’s rotation around the X axis of O¹ by θ₁ degrees (creating frame O²), and Equation 3 represents the mirror’s rotation around the Y axis of O² by θ₂ degrees (creating frame O₃). O₃ is the orientation of the fully adjusted mirror. We can combine these three equations to create the forward kinematics of our robotic arm:

\[
R_1^0 = R_{Z_0, \theta_0} = \begin{bmatrix} \cos(\theta_0) & -\sin(\theta_0) & 0 \\ \sin(\theta_0) & \cos(\theta_0) & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{1}
\]

\[
R_2^1 = R_{X_1, \theta_1} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\theta_1) & \sin(\theta_1) \\ 0 & -\sin(\theta_1) & \cos(\theta_1) \end{bmatrix} \tag{2}
\]

\[
R_3^2 = R_{Y_2, \theta_2} = \begin{bmatrix} \cos(\theta_2) & 0 & \sin(\theta_2) \\ 0 & 1 & 0 \\ -\sin(\theta_2) & 0 & \cos(\theta_2) \end{bmatrix} \tag{3}
\]

Thus, the orientation of the mirror can be determined when given the joint angles θ₀, θ₁, and θ₂, using Equation 5. During calibration, the forward kinematics equation can be used to determine the position (direction, since distance is irrelevant) of the rear-view mirror to be tracked. When the mirror has been adjusted by the user (giving us θ₀, θ₁, and θ₂) for recalibration, an image of the user will be processed to find θ_Y and θ_Z. θ_Y and θ_Z tell us the rotations from O³ needed to point the normal vector of the mirror directly at the user’s eyes. Using the forwards kinematic equation, and these five angles, the direction of the “frame to track” can be derived as follows:
With the direction to the window known, the mirror's pitch and yaw can be adjusted (with respect to the user's eye position) such that the virtual image of the window is always in the center of the mirror. While Equation 9 is used to calculate \( P_{\text{Window}}^0 \) initially, when \( P_{\text{Window}}^0 \) is known Equation 9 is used to calculate the desired pitch and yaw such that the virtual image of the rear window is centered in the rear-view mirror. As a result, Equation 9 is used to point the normal vector of the mirror in the correct direction. To determine the desired roll of the mirror, the window not only needs a direction, but an orientation. The following axioms are used to assign an orientation to this frame:

\[
R_{\text{Virtual}}^3 = \begin{bmatrix}
-1 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 1 \\
\end{bmatrix} R_{\text{Window}}^3
\]

\[
Y_{\text{Virtual}}^3 = \begin{bmatrix} c \\ d \\ 0 \end{bmatrix}, \|Y_{\text{Virtual}}^3\| = 1
\]

\[
X_{\text{Window}}^0 = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}
\]

Equation 10 represents reflecting the window's frame across the plane with normal vector \( X^0 \) to create the window's virtual image. Equation 11 implies that the projection of \( Y_{\text{Virtual}}^3 \) onto the mirror plane is perpendicular to the mirror's Z axis, \( Z^3 \). While it may seem like a good idea to set \( Y_{\text{Virtual}}^3 \) equal to \( Y^3 \) during calibration, this may result in an undesired roll when the user is in different positions. This is because Equation 11 has an infinite set of solutions (rotating around \( Z^3 \)). To select a single (and good) solution for the orientation of the window's frame, we apply Equation 12 as a constraint. This equation constrains \( X_{\text{Window}}^0 \) to be parallel to \( X^0 \). This constraint can be
interpreted as assuming the rear window will be pointing straight backwards (in the same direction as the unrotated rear-view mirror). With these constraints, both position and orientation of the rear window's frame of reference can be calculated. With this frame of reference fully characterized, properly adjusting the mirror's roll is just a matter of satisfying the following equations:

\[ Z^3 \cdot (Y^{Virtual} - (Y^{Virtual} \cdot X^3) \cdot X^3) = 0, (Y^{Virtual} - (Y^{Virtual} \cdot X^3)) \cdot Y^3 > 0 \quad (13) \]

The equality statement in Equation 13 enforces that the projection of \( Y^{Virtual} \) onto the mirror is parallel to \( Y^3 \). The inequality in equation 13 forces the projection of \( Y^{Virtual} \) onto the mirror to go in the same direction as \( Y^3 \) (since rolling the mirror 180° would align the mirror correctly but would still be undesirable). By solving these equations, we can implement software to achieve proper orientation of the mirror with three degrees of freedom.

2.5 Tolerance Analysis

One of our top level requirements is to achieve 3 degrees of accuracy. To achieve the desired 3 degrees of accuracy, the mechanical and software components of the system must maintain a high degree of accuracy.

The stepper motors used have step sizes of 0.9°. Errors cannot accumulate across multiple steps, meaning the system could only accumulate more than 3° of mechanical error if one of the motors were to slip more than 3 times.

\[ \left| \frac{3° \text{ of error}}{0.9° \text{ step}} \right| = 4 \text{ steps} \quad (14) \]

Given the torque of the motors, at present it seems unlikely that the motors will slip, and even more unlikely that they would slip enough times to fall outside the 3° tolerance range.

The eye tracking presents more of a concern. Depending on the quality of the neural net as well as external factors, such as sunlight, sunglasses, or facial coverings, the eye tracking can be expected to have some level of error.
At 3 feet (1m), the eye tracking would need to be accurate to within

$$1m \times \sin(3\degree) = 5.2cm (15)$$

At 5 feet (1.5m), the eye tracking would need to be accurate to within

$$1.5m \times \sin(3\degree) = 7.85cm (16)$$

Given the average pupillary distance (distance between pupils) for men is 64mm[7], this essentially means the eye tracking must at a minimum be capable of placing the center point of the user’s eyes somewhere between the user’s eyes.

3 Cost and Schedule
3.1 Cost Analysis

3.1.1 Labor

At a rate of $40 an hour, working approximately 15 hours a week for 16 weeks with 3 employees, the cost would come out to:

$$3 \times \frac{$40}{hr} \times \frac{15hrs}{week} \times 16 = $38,400 (17)$$
3.1.2 Parts

<table>
<thead>
<tr>
<th>Part</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>850nm IR Camera</td>
<td>$17.09</td>
</tr>
<tr>
<td>48 N.cm Stepper Motor (x3)</td>
<td>$16.95(x3)</td>
</tr>
<tr>
<td>850nm IR LEDs (x25)</td>
<td>$0.3252(x25)</td>
</tr>
<tr>
<td>5mm Screw Shaft Collar (x6)</td>
<td>$1.87(x6)</td>
</tr>
<tr>
<td>Hardware components (resistors, capacitors, connectors, sockets)</td>
<td>$15</td>
</tr>
<tr>
<td>3A 3.3v voltage regulator (x5)</td>
<td>$2.60(x5)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$115.29</strong></td>
</tr>
</tbody>
</table>

3.2 Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Adam</th>
<th>Derek</th>
<th>Tommy</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/7/18</td>
<td>Determine components necessary for CPU and stepper motor control circuit.</td>
<td>Test cover materials for mirror.</td>
<td>Derive closed form solution for orientating normal vector of mirror.</td>
</tr>
<tr>
<td></td>
<td>Create preliminary version of EAGLE schematic.</td>
<td>Source preliminary mirror materials.</td>
<td>Identify suitable momentary switches for use as limit switches for stepper motors.</td>
</tr>
<tr>
<td></td>
<td>Identify potential manufacturing processes for fabricating mounting mechanism.</td>
<td>Order motors, mounting hardware, LEDs, and components for CPU and stepper motor control circuit.</td>
<td>Make preliminary eye tracking software.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preliminary design voltage regulator circuit.</td>
<td>Make preliminary revision of mounting mechanism.</td>
</tr>
<tr>
<td>10/14/18</td>
<td>Design preliminary PCB for CPU and stepper motor control circuit.</td>
<td>Test out stepper motor circuit functionality via breadboard.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Test out stepper motor circuit functionality via breadboard.</td>
<td>Use breakout boards on CPU to test out CPU circuit design on breadboard.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Augment CAD model to include limit switches and calibration button.</td>
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</tr>
<tr>
<td>10/21/18</td>
<td>Determine method of manipulating mirror for manufacturing.</td>
<td>Deign a solution for imaging through mirror.</td>
<td>Derive closed form solution for roll of mirror.</td>
</tr>
<tr>
<td></td>
<td>Verify mounting mechanism and update CAD model to reflect any issues presented.</td>
<td>Order preliminary revision of PCB (preferably pre-populated).</td>
<td>Perform initial testing of software and getting images from camera.</td>
</tr>
<tr>
<td>Date</td>
<td>Activity Description</td>
<td>Task</td>
<td>Notes</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>-------------------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>10/28/18</td>
<td>Verify PCB functions properly, order second revision of PCB if errors are present.</td>
<td>Revise PCB.</td>
<td>Create preliminary</td>
</tr>
<tr>
<td></td>
<td>Update PCB design if errors are present.</td>
<td>Manufacture updated mounting mechanism.</td>
<td>control algorithm</td>
</tr>
<tr>
<td>11/4/18</td>
<td>Preliminary testing of fully assembled project.</td>
<td>Collect details regarding power consumption and safety</td>
<td>Explore V2 eye tracking solutions</td>
</tr>
<tr>
<td>11/11/18</td>
<td>Verify that PCB will work with power regulation circuit.</td>
<td>Verification testing: Motor, CPU, Power supply</td>
<td>Verification testing: button, IR Camera, IR LED</td>
</tr>
<tr>
<td>11/18/18</td>
<td>Final revisions to CAD model and PCB.</td>
<td>Solder V2PCB</td>
<td>Finalize eye tracking software</td>
</tr>
<tr>
<td></td>
<td>Thanksgiving Break: Order final revisions PCB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/25/18</td>
<td>Begin functional testing of final revisions.</td>
<td>Conduct environmental testing</td>
<td>Bug fix and smooth out control algorithm</td>
</tr>
<tr>
<td>12/2/18</td>
<td>Iron out any potential bugs that may become apparent at the last minute.</td>
<td>Begin final report</td>
<td>Begin final report and prepare for final presentation</td>
</tr>
</tbody>
</table>

4 Ethics and Safety

There are several potential safety hazards and ethical concerns with our project. The mirror will be used to safely control a vehicle, and the user will be constantly observed by a camera. Any failures on the part of the mirror could result in the loss of life not only the user, but anyone surrounding the user’s vehicle, as well as loss of the user’s privacy.

Any collected visual data is only transient and will not exist once the computations have been completed. This data cannot be stored by the system, and the hardware does not have any ability to transmit visual information to the outside world. A malicious agent would need physical access to the hardware and would need to make significant modifications to the hardware to access, store, or transmit any data collected by the system. The level of access and effort required for such an endeavor renders additional mitigation strategies pointless. With the necessary level of dedication and resources required for such an attack, an attacker would have ample other opportunities to violate the user’s privacy.

More concerning is the proper functionality of the hardware. The primary goal of this project is to improve driver safety and save lives. Catastrophic failure of the mirror could dramatically reduce driver safety and risks the lives of anyone in the vicinity of the user and their vehicle. Improper movements or loss of power would result in degraded
or totally obscured visibility to the rear of the user’s vehicle or may create blind spots which the user is unaware of.

While off, the motors will provide enough resistance torque (2.2N.cm) to keep the mirror in place, while remaining adjustable through physical movement. In the case of total power failure, the mirror will operate like a traditional rearview mirror. The user would face no additional hazards when compared to current alternatives.

The control system presents the greatest safety risk to the user, due to the number of unknowns and the required precision of the system. Edge cases or system faults could result in erratic behavior, substantially worse than the graceful failure which would happen due to power loss. The standard response to any unknown event would be for the mirror to remain fixed, to minimize errant behavior.

Though unexpected events should be expected, there are certain scenarios which can be planned for, and managed in software. A driver is likely to briefly glance over their shoulder or down at their center console, before returning to their normal driving position. A back-seat passenger may enter the camera’s field of view. Such eventualities can be handled in software. As a general rule, the system will avoid sudden shifts and add delay before reorienting itself, to make its responses more predictable to the user.

With a well-functioning camera system and properly functioning stepper motors, 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.

Another point of consideration is the use of IR LEDs. We will be shining a potentially dangerous amount of infrared light at the user, potentially risking eye cataracts or other permanent damage[8]. For our given application, 100 W/m of IR radiation is generally considered safe[9]. This output level is typically only a concern when working with lasers or other high-power applications. For our purposes, we assume the user will not be closer than 2 feet from the LED sources, which have a 40° angle of illumination and 75mW/sr maximum radiant intensity per LED. We will use at most 20 of these LEDs.

Using 40° as the solid angle, projected onto a sphere of radius 2 feet, we find that we will provide a maximum of 1W of illumination, over an area of 0.31m². This gives a maximum expected illumination of 3.4 W/m². Thus, our system, even with 20 LEDs operating at peak current, is not expected to cause any long-term or short-term injury.
\[ \Omega = \frac{40^\circ \pi}{180} = 0.70 \]

\[ \text{Illumination} (I_e) = 75 \frac{mW}{sr} \times \Omega \times 20\text{LEDs} = 1.05\text{Watts} \]

\[ \Omega r^2 = A \rightarrow 0.70 \times \left( \frac{2\text{feet}}{3\text{feet/meter}} \right)^2 = 0.31\text{meters} \]

In designing this project, we took into consideration the IEEE Code of Ethics[10]. We believe our design sufficiently adheres to the code, especially with regards to #1: “to hold paramount the safety, health, and welfare of the public”. Our project was motivated by a desire to protect the health and safety of the public, and the final design must produce a net gain in safety to the user, who is realistically trusting the system with their lives.
References


