IPRO 324
Enhancing the Functionality of Residential Garage Door Operator Using CCD Camera Technology
Industry Accident Statistics

1. Since 1990, an average of 20,000 people each year have been treated in hospital emergency rooms for injuries related to garage doors. (U.S. Consumer Products Safety Commission)

2. Sixty children under the age of 14 have been trapped and killed under automatic garage doors since March 1982. (U.S. Consumer Product Safety Commission)

3. Children accounted for approximately 15 percent of the total 22,431 garage door related injuries reported from January 1982 to December 1985. (U.S. Consumer Product Safety Commission)
Evolving UL Standards

- 1st Ed. (1973): 2 second reversal off 2” obstruction
- 2nd Ed. (1979): 30 second reversal off 2” compressible obstruction
- 3rd Ed. (1991): 30 second reversal off 1” compressible detection with external entrapment sensor
Purpose

- Chamberlain is investigating alternative sensors in an ongoing effort to improve their product line.
- Chamberlain has commissioned us to investigate the feasibility of replacing their current infrared (IR) emitter detector pair with a CCD Camera sensor.
Methodology

• Verified goals with Chamberlain
• Developed two theories
• Investigated approaches for feasibility
• Implemented comparison testing
Existing IR System

- Infrared beam is only 1 pixel wide
- Single beam runs less than 6 inches above the ground
- Obstacles can remain undetected if they do not break the beam
- Existing design can be improved
Enhancing the Current Design

- Increase the active scope of sensors
- Increase the reliability of obstruction detection
- Reduce the probability of damage/injury
Current Standards and Regulations

- Door MUST reverse upon encountering an obstacle (50 cycles test)
- Local conditions set to most hostile
- Additional tests depending on complexity of garage door
Current Standards and Regulations

- Reversal of door
  - Must return to upper most location
  - Must stop

- Door movement monitored at increments no greater than 1 inch
User Needs and Requirements

- Must be SAFE
- Must be affordable
- Must be easy to setup & maintain
- Must be reliable
How it works

Start → Initialize → Calibrate → Get Image → Process Image → Verify Data → Detect Obstruction → Yes

Yes → Signal Garage Door

No → Detect Obstruction
How it works

Start

Initialize

Calibrate

Get Image

Process Image

Verify Data

Detect Obstruction

Yes

Signal Garage Door

No
How it works

Start ➔ Initialize ➔ Calibrate ➔ Get Image ➔ Process Image ➔ Verify Data ➔ Detect Obstruction ➔ Signal Garage Door

Yes ➔ Yes

No ➔ No
How it works

Start → Initialize → Calibrate → Get Image → Process Image → Verify Data

Yes → Detect Obstruction → Yes

No

Signal Garage Door
How it works

1. Start
2. Initialize
3. Calibrate
4. Get Image
5. Process Image
6. Verify Data
7. Detect Obstruction
8. Yes → Signal Garage Door
9. No
How it works

Start → Initialize → Calibrate → Get Image → Process Image → Verify Data → Detect Obstruction

Yes → Signal Garage Door

No → Calibrate → Get Image → Process Image → Verify Data → Detect Obstruction
How it works

Start

Initialize → Calibrate

Get Image → Process Image → Verify Data → Detect Obstruction

Signal Garage Door

Yes → Detect Obstruction → Yes

No
How it works

Start

Initialize

Calibrate

Get Image

Process Image

Verify Data

Detect Obstruction

Signal Garage Door

Yes

No
Obstruction Detection

Two Approaches

Comparison Testing

Object Recognition
## Comparison vs. Recognition

<table>
<thead>
<tr>
<th></th>
<th>Comparison</th>
<th>Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code Complexity</td>
<td>Simple</td>
<td>Very Complex</td>
</tr>
<tr>
<td>Feasibility</td>
<td>Relatively little development time</td>
<td>Large R&amp;D effort</td>
</tr>
<tr>
<td>Cost</td>
<td>Moderate cost</td>
<td>High Cost</td>
</tr>
<tr>
<td>Reliability</td>
<td>More Reliable</td>
<td>Less Reliable</td>
</tr>
</tbody>
</table>
Cross Correlation

Original Image

Scale of Correlation

0.125  0.25  0.375  0.5  0.625  0.75  0.875  1.0
**Sum of the Squared Differences**

<table>
<thead>
<tr>
<th>Target strip pixels</th>
<th>Captured image pixels</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>255</td>
<td>32</td>
</tr>
<tr>
<td>33</td>
<td>16</td>
</tr>
<tr>
<td>16</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>21</th>
<th>129</th>
<th>55</th>
</tr>
</thead>
<tbody>
<tr>
<td>255</td>
<td>30</td>
<td>233</td>
<td>109</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>16</td>
<td>60</td>
<td>254</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>8</td>
<td>48</td>
<td>16</td>
<td></td>
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</tbody>
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\[ \text{SSD} = \sum (\text{target-captured})^2 \]
**Sum of the Squared Differences**

\[
\text{SSD} = \sum (\text{target} - \text{captured})^2
\]

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<thead>
<tr>
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<tr>
<td>0 20 128 55</td>
<td>2 21 129 55</td>
</tr>
<tr>
<td>255 32 233 109</td>
<td>255 30 233 109</td>
</tr>
<tr>
<td>33 16 64 255</td>
<td>32 16 60 254</td>
</tr>
<tr>
<td>16 8 48 16</td>
<td>17 8 48 16</td>
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</table>

\[
\text{SSD} = 4
\]
## Sum of the Squared Differences

$$SSD = \sum (\text{target} - \text{captured})^2$$

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<td>16 8 48 16</td>
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$$SSD = 1$$
## Sum of the Squared Differences

SSD = \[ \sum (\text{target} - \text{captured})^2 \]

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<tr>
<td>255, 32, 233, 109</td>
<td>255, 30, 233, 109</td>
</tr>
<tr>
<td>33, 16, 64, 255</td>
<td>32, 16, 60, 254</td>
</tr>
<tr>
<td>16, 8, 48, 16</td>
<td>17, 8, 48, 16</td>
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SSD = 1
**Sum of the Squared Differences**

\[
\text{SSD} = \sum (\text{target} - \text{captured})^2
\]

Total SSD = 29

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</tr>
<tr>
<td>16 8 48 16</td>
<td>17 8 48 16</td>
</tr>
</tbody>
</table>
Calibration

Target

Captured

SSD = 104
Calibration

SSD = 230
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<tr>
<th>Target</th>
<th>Captured</th>
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**SSD = 100**
<table>
<thead>
<tr>
<th>Target</th>
<th>Captured</th>
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<tr>
<td></td>
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</table>

**SSD = 7**
Calibration

Target

SSD = 345

Captured
Calibration

Target

Minimum SSD = 7

Captured
Demonstration
Marketing Strategy

• Target Market - Who are the customers?
Marketing Strategy

• Target Market - Who are the customers?

Since the CCD camera is only meant to enhance or replace the IR transmitter-receiver, the target market currently used by Chamberlain should not change.
Marketing Strategy

• How much will our selected market spend on our product?
Marketing Strategy

• How much will our selected market spend on our product?

Price range is from $129 - $249 depending on Drive system:

1. Belt Drive
2. Chain Drive
3. Screw Drive
Marketing Strategy

- Competition – Who are the competitors with similar products?
Marketing Strategy

• Competition – Who are the competitors with similar products?

Genie, Wayne-Dalton, and many other smaller companies, however, Genie is the largest company competing with Chamberlain.
Product Specifications

- Architectural Specs & NEMA Standards
- UL (Underwriters Laboratory)
- FCC (Federal Communications Commission)
- NEC (National Electrical Code)
Comparison to IR System

- More Costly
- Slower response time (Unnoticeable to human perception)
- Larger scope of obstruction detection
- New
Future Plans

- Continue research by building a working prototype

- The prototype should:
  - Function in varying lighting conditions
  - Pass current UL standards
  - Support an additional camera to eliminate any blind spots
  - Run as an embedded application
Questions