**Background**

Clemens Food Group (CFG) is a sixth-generation family-owned company that includes hog farming, multiple state-of-the-art food processing facilities, logistical services, and transportation. They are the fifth largest pork processor in the United States and an industry leader in providing premium quality pork products for retail, foodservice, and further processors. A CFG cornerstone is to “never compromise on food safety” and they have invested in a first-class inline X-ray fat trim/blend re-inspection conveyor, and staff (for visual inspection) to provide unparalleled food safety and quality. As the fifth generation family-owned company that includes hog farming, multiple state-of-the-art food processing plants; such as gloves, hairnets, plastics, stainless steel, etc., in an effort to minimize the manual labor dedicated to the trim/blending line. A series of tests were completed to identify the ideal detection tool along with its foreign object detection accuracy and size limitation with a CFG supplied Keyence Vision Sensor with built-in AI (IV3 Series), a conveyor like their trim/blender re-inspection conveyor, and pork trim.

**Objectives**

The team must train the smart camera for foreign objects (Figure 1). The goal is to implement on the production floor and report on successes and failures.

- Detect ≤ 7mm (0.28in)

**Design Alternatives**

The camera software offers several different methods for training the camera to detect foreign objects (Figure 2).

**Design Parameters**

Using the color prohibit tool, three designs were drafted on how the Keyence cameras should be placed on the line. Design 1 includes two cameras side by side on a bridge-like mount on top of CFG’s already installed line. Design 2 is like Design 1 with a roller installed before the camera mount to ensure maximum trim surface area in the camera’s field of view. Design #3 consists of a roller, two Keyence cameras, a waterfall conveyor, and two more Keyence cameras down the line (Figure 3). The pork would be flattened by the roller and the first two cameras check for foreign objects. The pork is then flipped onto its other side by the waterfall conveyor. Two more cameras check for foreign objects once again before continuing to the blend line. This allows for more surface area in view for optical foreign object detection.

**Selected Design**

- Color prohibit has a high degree of accuracy and sensitivity.
- All three methods have similar detection potential, but color prohibit seems to be much easier to train.
- Color prohibit was the best method for achieving the desired outcome (Table 1).

**Economics**

Implementing a vision system would save Clemens $75,000 annually from removing/reducing the cost of hiring for human visual inspection. This is the base-case scenario used for economic analysis when comparing suggested alternative vision systems.

- The cost of four potential vision systems were compared (Table 2).

**Table 1. Keyence Camera programming weighted decision matrix.**

<table>
<thead>
<tr>
<th>Design Method</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Detection Rate</th>
<th>Ease of AI Training</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Color Prohibit</td>
<td>360</td>
<td>270</td>
<td>160</td>
<td>80</td>
<td>870</td>
</tr>
<tr>
<td>Color Average</td>
<td>280</td>
<td>150</td>
<td>160</td>
<td>60</td>
<td>650</td>
</tr>
<tr>
<td>Learning</td>
<td>200</td>
<td>210</td>
<td>160</td>
<td>40</td>
<td>650</td>
</tr>
</tbody>
</table>

**Table 2. Cost estimation of vision systems.**

<table>
<thead>
<tr>
<th>Vision System</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>P&amp;P Smart Imaging System</td>
<td>$750,000</td>
</tr>
<tr>
<td>Marel (OC Scanner/Sensor X Magna)</td>
<td>$1,100,000</td>
</tr>
<tr>
<td>Keyence Vision Sensor (IV3) - Final Design</td>
<td>$98,000 - $117,600</td>
</tr>
</tbody>
</table>

Despite the cost of four potential vision systems, the P&P vision system is the most accurate but also one of the most expensive.

**Conclusion**

The Keyence camera was optimized and tested for limitations it would have during use in the CFG facility. The results showed the camera had poor detection rates and false negatives when not zoomed in. During 2x magnification, the orange glove showed a higher detection rate than the blue glove (Table 4).

- 2x false positive rate = 5.77%

The Keyence camera needs to be trained to implement the Keyence camera, our team recommends the P&P smart imaging system with additional components (Table 3).

**Select References**
