TEXAS A&M UNIVERSITY
Engineering

Robotic Fruit Sorting System

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Problem Definition

The United States has a burgeoning agriculture industry that, through over 2 million small-scale farms, contributes over $140 billion in agricultural exports to the American economy. However, farmers and ranchers only receive 8 cents of every dollar that the end consumer spends on food. A significant amount of time and effort goes to overhead costs such as labor and processing [1]. The Robotic Fruit Sorting System ("Robotic Sorting System" or "RSS") is designed to reduce labor costs by reducing the manpower needed to check agricultural products for defects and proper size, keeping more money in farmers' pockets and reducing the number of defective fruit that makes it to store shelves (which may otherwise be wasted due to its negative appearance). The Robotic Sorting System is particularly designed for smaller-scale farming operations, as currently available sorting machines tend to cost thousands of dollars and are designed for large-scale operations [2].

Methodology

To bring the benefits of automated fruit sorting to even the smallest-scale farming operations, it is necessary to use cost-effective methods of classifying fruit in conjunction with a low-cost physical sorting apparatus. While the solution must be cost-effective, it must also be highly accurate and reliable to replace manual sorting. The following features are the Robotic Sorting System's key to accomplishing these goals.

ANDROID APPLICATION

The end user controls the Robotic Sorting System with a free Android application that connects to the Robotic Sorting System through Bluetooth. Since Android is by far the most popular mobile operating system in the world [3], Android devices are widely available at many price points. This configuration significantly reduces the complexity and cost of the RSS itself.

RASPBERRY PI FRUIT CLASSIFICATION

The Robotic Sorting System uses an onboard Raspberry Pi 4 to classify fruit by color and size for sorting. It also uses machine learning to distinguish spoiled fruit from non-spoiled fruit. This functionality gives the customer a highly capable and cost-effective solution thanks to the Raspberry Pi's low cost and high availability in combination with the Robotic Sorting System's proprietary hardware.

LIMITED-BIN FRUIT SORTING

While sorting fruit into many individual "bins" may be helpful for large-scale farming operations, not all operations require such broad sorting capability. The Robotic Sorting System sorts fruit into two or three bins (as configured by the user), providing basic sorting capability without unnecessary complexity and cost.

Engineering Analysis

For the analysis of the various buck converters, see Table 1. The Printed Circuit Board is also viewable in Figure 1.

The voltages were checked with an oscilloscope and the waveform was analyzed for noise.

Digital image processing was used to determine if a pixel belonged to the background or to the fruit. With the fruit separated from the background, the color and size of the fruit could be measured. A machine learning (ML) model was trained with label images of good lemons and bad lemons.

Table 1. Buck Converter Analysis

	Input Voltage (Actual Input)	Expected Output	Actual Output	Error
Vcc (Motor Controller Input Voltage)	12 V (12.135)	4 V	Max: 4.06 V Min: 3.915 V	Avg: 3.9875 V Error: 0.3125 %
Raspberry Pi Input Voltage	12 V (12.135)	5 V	Max: 5.142 V Min: 4.989 V	Avg: 5.0655 Error: 1.31 %
ADC Input Voltage	12 V (12.135)	3.3 V	Max: 3.316 V Min: 3.284 V	Avg: 3.3 V Error: 0 %
Op Amp Input Voltage (Positive, Negative)	12 V (12.135)	±5 V	Max: 5.567 V, -5.433 V Min: 5.406 V, -5.584 V	Avg: 5.487 V, -5.515 V Error: 9.73 %, 10.27 %

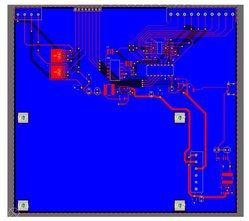

Figure 1. Printed Circuit Board design

Figure 2. Steps of image processing to separate the fruit from the background

Outcomes

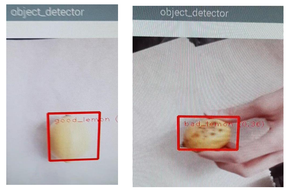

Figure 3. ML model detecting a good lemon vs. a bad lemon.

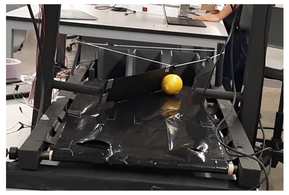

Figure 4. The conveyor belt system moves the good lemon to the first bin

CHALLENGES

While the Robotic Sorting System is capable of basic sorting, the system could be improved beyond its current state to provide more value to the customer and to improve its overall reliability.

- **Bluetooth Interaction with App:** While the Bluetooth connection is fully functional, there are some small issues impacting the user experience.
- **Bluetooth Interaction with App (cont.):** The app disconnects and reconnects with the system every time the screen changes, which is necessary to refresh the screen, but adds wait time when moving between screens. Additionally, the Bluetooth connection takes about 10 seconds and occasionally fails to connect entirely, which would be problematic in a production model.
- **Designing the Printed Circuit Board (PCB):** Designing a PCB was difficult due to the lack of training in Altium prior to capstone. Debugging a PCB was also difficult as none of the ECEN department classes taken taught making circuits or debugging circuits.
- **Mechanical Engineering Design:** No one in the team had any experience with mechanical engineering, so building the system from scratch with no prior knowledge was a steep learning curve.

Impact

In its current form, the Robotic Sorting System is clearly in a prototype state, but the results it has achieved for a relatively low price (less than $500) show promise for the concept of low-cost fruit sorting. Given further time and resources, the most obvious improvements to the system would be a more robust conveyor belt/guiding arm system and a better-organized wiring setup along with software that is less problematic and is better able to handle edge cases.

References

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2. https://www.alibaba.com/showroom/fruit-sorting-machine.html
3. https://www.statista.com/statistics/272698/global-market-share-held-by-mobile-operating-systems-since-2009/

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