3D Inspection Rover

Christopher Dumont

Dalton Hines

Felipe Villegas

Celeste Waters

**Concept of Operations**

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Concept of Operations

for

3D Inspection Rover

Team 08

Approved by:

Kevin Nowka 12-03-2022

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Project Leader Date

Jang 12-03-2022

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Prof. Jang Date

Eric Robles 12-03-2022

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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# Executive Summary

To increase tomato production in regions that cannot be grown year-round, green houses are being utilized to lengthen the tomato growing season. However, this is costly, because of materials, man hours, and lack of autonomous options. We will be creating an automated option to inspect tomatoes which will decrease man hours needed and classify the produce without human input. The rover will navigate the aisles of the greenhouse avoiding obstacles and progressing to each plant ensuring none are missed. Using a depth sensing camera to capture and analyze images of the produce, the 3D Inspection Rover can determine ripeness via color and yield via size. Through these techniques, 3D Inspection Rover. will help achieve greater efficiency in the harvesting process of tomatoes.

# Introduction

This document is an introduction to a 3D Inspection Rover, a system capable of monitoring produce in a greenhouse, and informing farmers of the inspected plant’s yield and growth time to maturity. The rover. It will serve as a produce analyzer to help farmers identify which produce has the desired characteristics for optimal production and navigate around any obstacles it may face in aisle while inspecting. The system will also aid the efficiency of man hours by alerting farmers to which tomatoes are defective so they may be removed before infecting other tomatoes.

## Background

Related projects and research have been attempted before by using histograms of oriented gradients (HOG) which had a precision rate of 94% for telling if a tomato was ripe or not. 3D Inspection Rover will add onto this process by determining if the tomato has a disease and by classifying the tomato into 6 separate degrees of ripeness. This system will efficiently and autonomously identify and organize every image of produce to simplify the task for a human operator to go through the greenhouse and remove problem produce and pick ripe produce.

## Overview

The farmer activates the rover to begin traversing and documenting. The rover will stop at every plant within the greenhouse and take detailed pictures of each. The on-board computer will then process these images by identifying each tomato, determine its ripeness level or if it is sick and represent this data through graphs on a website for the farmer to easily track his product.

## Referenced Documents and Standards

|  |  |  |
| --- | --- | --- |
| Document Name | Revision/Release Date | Publisher |
| Learning Python | 4th Edition | O’Reilly |
| Image Processing | 2nd Edition | John Wiley & Sons |
| 2022 Complete Python Bootcamp Form Zero to Hero Python | 2022 | Udemy |

Table 1: Reference Documents

|  |  |  |
| --- | --- | --- |
| Feature Extraction and Image Processing | 2013 | Safari, an O’Reilly Media Company |

# Operating Concept

## Scope

The 3D Inspection Rover is designed for greenhouses to identify and sort produce, in this case tomatoes, into separate sections depending on their ripeness or if they are sick. This system is designed to decrease the cost of farmers operating large greenhouses by cutting out unnecessary work hours that typically would have been used to employ a person to walk through the greenhouse and manually document the mentioned specifications.

## Operational Description and Constraints

An operator will first turn on the raspberry pi and wait for it to go through its boot up process. The operator will then connect their laptop to the raspberry pi and execute the proper command to make the machine begin its process of moving and collecting data. At this point 3D Inspection Rover will be operating autonomously, locating every tomato plant, and classifying it.

|  |  |
| --- | --- |
| Constraint | Reasoning |
| Storage | The raspberry pi has limited on-board storage, so there is a limit to how many photos can be saved and processed. The use of an external SSD or cloud storage will help solve this problem; although cloud storage may also not be possible due to a lack of Wi-Fi within a greenhouse. |
| Terrain | The ground in the greenhouse, if it is dirt, could become muddy due to the irrigation system. If the ground, gets too muddy the rover will not be able to drive around and operate smoothly. |
| A.I. Capability | Due to limited time and budget, the machine learning software will be restricted in how much training it receives for each category of tomato. Because of this, false negatives/positives are inevitable. |
| Battery Life | There is limited size and room for the rover to operate in, this leads to a constraint on battery size. The effect this will have been that it will limit the size of a greenhouse the rover can scan in one charge. |

Table 2: Constraints of 3D Inspection Rover and reasonings

## System Description

The motors will be driven to precisely traverse the greenhouse, powered by an integrated battery system. The camera positioning will be controlled by more precise computer guided motors. The on-board computer systems and camera will be powered by a separate battery system to better manage power needs. The computer will take pictures through an on-board camera; the picture will be sent to a processing program to sort the tomato state and store it properly. Finally, the computer will move the rover to the next plant and repeat the process.

Diagram

Description automatically generated

Figure 1: System Overview Block Diagram

## Modes of Operations

The 3D Inspection Rover will only have one mode of operation, which is completely autonomous. In this mode, the rover will need to be turned on, and an external user will run the program written on a raspberry pi before it begins patrolling the greenhouse examining every tomato in the building. The image will then be processed in real time and placed into a CSV file and sent to a database and website to be accessed by humans later. Then returning to where it started to be charged at the end of the day.

## Users

The rover will be marketed to both small-scale and large-scale farmers who plan on growing produce inside of a greenhouse. This will help to lessen man hours needed to monitor the produce and require less people to monitor large areas.

The 3D Inspection Rover can also be modified to work outdoors, which would increase the number of farmers it can benefit. This could save farmers everywhere a considerable sum of money since there will need to be less people monitoring the fields looking for sick produce and determining current yield.

## Support

Information on how to make basic repairs will be provided in a user manual. Also included in the manual will be a list of every part and how it contributes to the operation of the rover. 3D Inspection Rover will come with all necessary software pre-installed along with detailed instructions on how to connect the operating software to a laptop so that data can be accessed at the end of the day and the rover can be started at the beginning of the day.

# Scenario(s)

## Ripe Tomato

In this scenario, the tomato is ripe and ready to be picked. The tomato should be a bright red and round and from there the processor should sort the tomato into the ‘red’ category, so that the farmer can mark it for harvesting.

## Unripe Tomato

In this scenario, the tomato is not ripe and should not be picked. The tomato is likely a shade of green and egg shaped. The processor will recognize this and sort the tomato into the ‘green-light red’ categories, so that the farmer knows to wait and check back later.

## Defective Tomato

In this scenario, the tomato is defective in some way and should be discarded. The tomato could be discolored, rotten, et cetera and from there the processor should sort the tomato into the “defective” category, so that the farmer can mark it to be discarded or composted.

# Analysis

## Summary of Proposed Improvements

Areas of improvement provided by 3D Inspection Rover include:

* Automation of produce classification
* Recognition of diseased plants
* Lower cost to farmer
* Higher quality produce for the public
* More accurate and accessible information for the farmer

## Disadvantages and Limitations

Disadvantages include constant chance of error that is inherent with machine learning in any scope. Additionally, there are strict budget and time limitations that prevent the machine from having top-of-the-line parts and programming. These limitations act together to affect overall accuracy and quality.

## Alternatives

An alternative to this solution would be to put the rover on a track system much like a train, this would simplify the autonomous motion needed to drive the rover around since no steering programming would be needed. This could lead to issues such as the track being wet and the machine sliding past where it was supposed to stop or jumping off the track if something were sitting on it.

There is also a variety of other programming languages that could be used instead of python as well as other microcontrollers beside the raspberry pi that will have strengths and weaknesses.

## Impact

The impact of this project is to save farmers money by not having to employ as many farms’ hands. This will have a positive environmental impact since there will be less people commuting to and from the farm, cutting down on greenhouse gas emissions. It will also improve quality of life for everyone that the farm provides produce to by increasing the quality of produce and since the operating cost is lower to the farmer, the produce can be sold for less, further benefiting the consumer. There are ethical concerns that come with automation taking the jobs of people, but these do not apply to the 3D Inspection Rover as it is made to aid those workers by automating a tedious and time-consuming task, freeing them for other tasks.