3D Inspection Rover

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**Functional System Requirements**

REVISION – 2

03 December 2022

Functional System Requirements

for

3D Inspection Rover

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**Change Record**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Rev.** | **Date** | **Originator** | **Approvals** | **Description** |
| **1** | [02/23] | 3D Inspection Rover | Robles, Nowka | Revision 1 |
| **2** | [04/30] | 3D Inspection Rover | Robles, Nowka | Revision 2 |
| **3** | [12/03] | 3D Inspection Rover | Robles, Nowka | Final |

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# Introduction

## Purpose and Scope

The capability of farmers to receive information accurately and reliably about their produce is paramount when it comes to running a profitable farm. In place of having a worker classify the greenhouse one tomato at a time our goal is to provide an automated rover that will classify every tomato by type. The 3D Inspection Rover will achieve this through a machine learning program that will sort images taken by an onboard camera. With the data achieved through the program, useful charts and graphics can be generated to inform the farmer of problem tomatoes, expected yield, and number of ripe and unripe tomatoes. This will allow the farmer to focus on other parts of the farm, saving them time and money. Our system will reduce overall man hours needed and is scalable to larger products by simply adding a larger battery onboard. It will also decrease the likelihood of a tomato being damaged during the inspection process because the rover will have no need to touch it which could potentially knock it off the plant and damage it.

Diagram

Description automatically generated

Figure 1: Conceptual image of Project

## Responsibility and Change Authority

Kevin Nowka, the team leader, is responsible for ensuring all requirements of the project are met. These requirements can only be changed by the approval of the team leader and Professor Jang.

|  |  |
| --- | --- |
| Subsystem | Responsibility |
| Autonomous Navigation | Chris Dumont |
| Camera Positioning | Dalton Hines |
| Image Classification | Felipe Villegas |
| Data accessibility and organization | Celeste Waters |

Table 1: Subsystem Leads

# Applicable and Reference Documents

## Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

|  |  |  |
| --- | --- | --- |
| **Document Number** | **Revision/Release Date** | **Document Title** |
| SH-16586-07-06-F-36 | 2007 | Electrical Safety: Participant Guide |
| STD-112-1996 | Revision-2004 | IEEE Standard Test Procedure for Polyphase Induction Motors and Generators |
| 1926.756 | 2001 | Beams and Columns: Safety and Health Regulations for Construction |

Table 2: Applicable Documents

## Reference Documents

The following documents are reference documents used in developing this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

|  |  |  |
| --- | --- | --- |
| **Document Number** | **Revision/Release Date** | **Document Title** |
| 1 | 2002 | National Electrical Code Allowable Ampacities of Insulated Conductors Rated 0-2000V |
| 1 | 1999 | Structural Steel Design: Structural Engineering Handbook |

Table 3: Reference Documents

## 2.3 Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings, or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents referred to in an applicable report are for guidance and information only, except ICDs that have their relevant documents considered incorporated as cited.

# Requirements

## System Definition

The 3D Inspection Rover is a replacement for humans when the task at hand is classifying tomatoes as they grow in a greenhouse. It allows for reduced man hours and thus a lower operating cost to the farmer. The 3D Inspection Rover has four subsystems: Autonomous Navigation, Camera Positioning, Image Classification, and Data Accessibility/Organization.

Diagram

Description automatically generated

Figure 2: Block Diagram of System

There will be two on board batteries, one for driving the motors, the other for powering the computer, camera, and distance sensors. These batteries will need to be recharged at the end of every operating cycle. The camera and distance sensors will provide input information to the computer which will be running an obstacle detection and image tracking program to determine the best route to the nearest plant. Once at the plant the motors will stop moving and allow the camera positioning system to take multiple pictures of the plant to be sent for further processing from the machine learning program. The camera will be plugged directly into the computer to reduce the need for a transmitter. The machine learning program will then sort the tomatoes by location, ripeness level, and defectiveness. Once the computer has this information it will be uploaded to a cloud server which will use it to create useful graphics for the farmer.

## Characteristics

### Functional / Performance Requirements

#### Plant Detection Pass Rate

The system is expected to recognize 75-80% of the plants

*Rationale: The system is subject to* *strict budget restrictions; this limits the quality of camera we can use and results in less than perfect data.*

#### Tomato Classification Pass Rate

The Machine learning program will accurately classify tomatoes 60-80%

*Rationale: Like the previous rationale the lower quality camera results in messy images. The limited* *period for the project also limits the amount of time the machine learning algorithm can be trained in tomato recognition.*

### Physical Characteristics

#### Height

The height of the rover’s camera lifting mechanism must be at least 4 ft tall.

*Rationale: This requirement was specified by the sponsor because the highest a tomato plant will be is 8ft tall, and we need to document the entire plant.*

#### Run Time

The rover needs to be able to run long enough to document every tomato in the greenhouse on one charge. This will vary by greenhouse size. The current configuration can reliably run for 6 hours.

*Rationale: This is important to reduce the number of incomplete runs and locate the rover if it dies.*

#### Width

The rover is currently 2.5 ft wide and needs to stay as such. Nothing we add may make it wider.

*Rationale: This is because there is limited aisle space for the rover to navigate.*

#### Length

The rover is currently 3 ft long, we may increase the length slightly with our sensors if necessary.

*Rationale: The rover still needs to make tight turns around the greenhouse so keeping the length limited is important.*

### Electrical Characteristics

#### Inputs

The lack of any input shall not damage the microcontroller in any way. Similarly multiple inputs from one sensor, nor any combination of inputs will damage the microcontroller, or reduce its life expectancy in any way.

*Rationale: We do not want the microcontroller to break because operation would come to a standstill until it is replaced.*

##### Power Consumption

The maximum peak power of the motors shall not exceed 144 watts. The maximum peak power of all other systems shall not exceed 15 watts

Rationale: This is because we want both batteries to have a similar life expectancy.

##### Input Voltage Level

The input voltage level for the motors shall be +24 volts, while the input voltage for all other systems shall be no more than +3.3 to +5 volts.

*Rationale: This is because the pieces are rated for these values.*

##### Input Current Level

The output current from the large battery is not to exceed 25 Amps, while the output voltage for the small battery is not to exceed 3 Amps.

*Rationale: The motor driver is rated for 25 amps while the Raspberry Pi is rated for 3 amps.*

#### Outputs

No outputs created by the system will be capable of damaging the system.

*Rationale: This is so the rover is not capable of damaging itself under any circumstances.*

##### Data Output

The system can upload data to a cloud computing site.

*Rationale: This allows the data to be stored and computed more effectively since there is limited onboard storage space as well as computing power.*

##### Raw Video Output

The system will hold pictures of problem tomatoes to be sorted later by a human, as well as an image of sick tomatoes so the farmer may remove it manually later.

*Rationale: This is important because there is a lack of internet in a greenhouse and allowing the farmer to view the problem tomatoes.*

#### Connectors

The microprocessor will have a removable SD card, that can be plugged into any viable computer

*Rationale: The system requires this because there is a lack of Wi-Fi in greenhouses.*

#### Wiring

The wiring used will follow IEEE and NEC standards for the expected power levels.

*Rationale: The system uses this because it is important for the safety of people and property.*

### Environmental Requirements

While the system is operating water sprinklers will need to be shut off. All other environmental requirements will be met by the rover.

*Rationale: The rover is not waterproof, so there could be a safety hazard and system failure.*

#### Thermal

The onboard computer is rated for 0 degrees Celsius to 85 degrees Celsius, all other systems will also operate within this range.

*Rationale: The computer can only operate within a limited range to prevent damage.*

#### Water Sprinklers

Sprinklers will have to be shut off during machine operation.

*Rationale: The rover is not waterproof, so there could be a safety hazard and system failure.*

#### Humidity

Humidity will need to be low during machine operation, below 50%

*Rationale: The humidity could cause short circuiting to occur so keeping within the limits is important for operational effectiveness and safety.*

### Failure Propagation

The B.O.B shall not allow propagation of faults beyond the subsystem it originated in.

#### Failure Detection, Isolation, and Recovery (FDIR)

The 3D Inspection Rover will have failure detection in the form of a system check at the beginning of operation. It will test motor control as well as sensor and camera operation. Every day when the system starts up, it will request a stream from the camera as well as a reading from each distance sensor. During operation, these items will be in use constantly, so if one fails, it will instantly be known by the system. If a sensor fails to operate the user will be notified so that the problem device can be replaced or repaired.

##### Built In Test (BIT)

The 3D Inspection Rover may have an internal subsystem that will generate test signals, evaluate the 3D Inspection Rover responses, and determine if there is a failure.

###### BIT Critical Fault Detection

The BIT shall be able to detect a critical fault in the 3D Inspection Rover 90 percent of the time.

*Rationale: This is a requirement specified by our customer due to the constraints of their system in which the B.O.B is integrating.*

###### BIT False Alarms

The BIT shall have a false alarm rate of less than 10 percent.

*Rationale: This is a requirement specified by our customer due to the constraints of their system in which the 3D Inspection Rover is entering.*

##### Isolation and Recovery

The 3D Inspection Rover should provide for fault isolation and recovery by enabling subsystems to be reset or disabled based upon the result of the BIT.

*Rationale: This is a requirement specified by our customer due to constraints of their system in which the Search and Rescue System is integrating.*

# Support Requirements

The 3D Inspection Rover only requires that it be charged at the end of every use session. Once it has scanned all tomatoes it will automatically upload to the cloud computing software so long as it has a Wi-Fi connection. The information will then be uploaded to a website. Nothing besides charging the batteries will be required of the farmer.

# Appendix A: Acronyms and Abbreviations

Below is a list of common acronyms and abbreviations, update based upon your project….

A Amp

BIT Built-In Test

CCA Circuit Card Assembly

EMC Electromagnetic Compatibility

EMI Electromagnetic Interference

EO/IR Electro-optical Infrared

FOR Field of Regard

FOV Field of View

GPS Global Positioning System

GUI Graphical User Interface

Hz Hertz

ICD Interface Control Document

kHz Kilohertz (1,000 Hz)

LCD Liquid Crystal Display

LED Light-emitting Diode

mA Milliamp

MHz Megahertz (1,000,000 Hz)

MTBF Mean Time Between Failure

MTTR Mean Time to Repair

mW Milliwatt

PCB Printed Circuit Board

RMS Root Mean Square

TBD To Be Determined

TTL Transistor-Transistor Logic

USB Universal Serial Bus

W Watt

V Volt

VME VERSA-Module Europe

# Appendix B: Definition of Terms

Fault Isolation: Process of identifying a fault in a system and preventing it from propagating to other subsystems.

Humidity: amount of water vapor in the air, expressed as a percentage of the maximum amount of water vapor the air can hold at the same temperature.