Automatic Guided Vehicle that detects Dactylopius Opuntiae in Cactus Pears

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Automatic Guided Vehicle that detects Dactylopius Opuntiae in Cactus Pears

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Abstract. Food security is one of the biggest challenges faced in Africa with drought being one of the leading factors. Cactus pear is a drought-resistant source of food for both animals and humans. They have become indigenous in South Africa and has maintained a role in the diet of the local population and animal feed. This food source needs to be monitored for Dactylopius Opuntiae. Dactylopuis is an insect that infests the Cactus Pear (Opuntia) and makes a cottony, waxy mass as shelter for the female and their eggs. Industry 4.0 led to the introduction of a subcategory namely Farming 4.0 also known as smart farming. This paper evaluates such a smart farming automatic guided vehicle (AGV) system that could navigate itself from plant to plant using Xbox Kinect and detect Dactylopius Opuntiae. Results show and discuss the navigation-speed and an example of the Dactylopius Opuntiae detection. The passive response could include an internet of things (IoT) approach that could send the GPS data of the infested plant to the farmer or an active approach could be an onsite hands-on application.

1. Introduction

Food shortages are a major problem in countless countries across Africa, with drought being one of the major leading factors. Prickly pear (opuntia) also referred in South Africa as sweet or mission prickly pear is of Mexican origin. The plant has a thick, woody trunk with stems of green flattened, narrow, elliptical segments or leaf pads called cladodes. Prickly pear produces orange flowers that develop to elliptical fruits with colors from yellow and orange to red and purple. The fruits is popular with humans, mammals and birds [1] The Grootfontein Agricultural Development Institute imported spineless Burbank (Opuntia ficus-indica) for drought-tolerant source of fruit and fodder, initially aimed at the arid Karoo regions in 1914 [2, 3, 4].

The purpose of this an Industry 4.0 Dactylopius Opuntiae detection AGV. Dactylopius is a cochineal insect that lives in colonies on the surface of cactus plants. Adult females cover themselves in a white woolly wax shelter for them and their eggs. This infestation can kill the plant and the whole crop. Their efficiency to kill a crop was used as a biological pesticide on the intrusive, extremely spiny cultivars that invaded 900000 ha as introduced in 1772 [2, 4].

This paper discusses key concepts and theories, followed by the construction and operation of an AGV with navigation and identification abilities. Results discuss the ability and limitation of the AGV and is followed by a conclusion.

A cactus pear automatic guided vehicle that can detect Dactylopius Opuntiae could be used via IoT to give the GPS location of infected plants or could more actively be utilized with an onsite application.

2. Literature review

To develop a cactus pear automatic guided vehicle that can detect Dactylopius Opuntiae the following needs to be discussed:

2.1. Cactus pear farming

Farming is the largest sector in an economy and plays an important role in development. A large percentage of the population depends on farming as a source of livelihood [6] Technological growth and the introduction of Industry 4.0 with Farming 4.0 also known as smart farming lead to an increase of technology to increase productivity in various farming activities. Food security is important in arid and semi-arid areas and the drought-resistant cactus pear plays an important role in the food as well as feed production [6, 4]. It is reported that Cactus pear (Opuntia spp.) was imported 1772 to South Africa, but better spineless cultivars were imported in 1914 from the United States. The spineless cactus pear (Opuntia Robusta) was established in the Karoo as drought-tolerant feed crops and the cladodes fed to livestock and O. ficus-indica are promoted for export [4]. Human consumption of the fruit in arid and semi-arid regions is contributed to its nutritional and medicinal properties [7]. Spineless cactus pear (O. ficus-indica) cladodes are sun-dried and used as major ruminant feed sources, with two of the largest cactus pear fruit producers in South Africa converting to livestock feed [4, 8].

2.2. Image processing

Basic image processing is understood to be obtaining an image through vision acquisition tools and analyzing/ altering the image to get an output based on the analysis of the image. There are two distinct types of image processing, analogue and digital image processing, but this study focus is solely on digital image processing. In a typical image processing system a digital image is obtained through a digital camera, where it is recognized and processed by vision acquisition software in real-time to obtain a particular outcome [9, 10]. Further analysis might be needed to classify the image based on a specific requirement. The image is segmented to focus on the specific regions of interest (ROI). The image could then be converted to a binary image using a threshold function [9]. A binary image only consists of 0 and 1. This will give the ability to do partial analyses but normally need an enhanced binary image. Enhancement includes function like eroding and filling. Eroding will remove noise and filling fills holes in the particle analyses blobs. A blob is calculated on the binary image if there is a large neighborhood of binary 1's in indicating a mass of interest [11, 10, 12]. Thresholding of a binary image is mostly done as an if statement comparator on grayscale image but can also be done on hue as a color threshold. Hue is part of the hue, intensity and saturation approach. Hue is measured in angle where the angle represents a color and is not related to saturation or intensity. Thus, for example, the same angle green will stay at that angle no matter the lighting.

2.3. Navigation 3D Image processing

The Microsoft Kinect sensor consists of a depth sensor, an RGB camera, multiple microphones and supports both facial and voice recognition capabilities. The 3D depth sensor could be utilized to 3D scan the environment for navigation processes. The 3D depth sensor uses an infrared projector, a laser that is turned into IR dots by passing through a diffraction grating and an infrared camera that perceives infrared energy [11].

2.4. AGV system

Developments in automation and Industry 4.0 sees a completely new range of agricultural equipment [15, 16, 12, 17, 18]. One of these industry4.0 technologies is an AGV. An AGV is defined as a programmable, self-controlled device consisting of electronic, electrical, or mechanical units [19, 20, 21]. A concept of AGV could be utilized as a base for an Automatic detector for Dactylopius Opuntiae.

2.5. LabVIEW

LabVIEW is a graphical programming language based on automation control and data acquisition. It has various key attributes that make it a preferable choice for an automation environment. Namely simple network communication, turnkey implementation of common communication protocols, powerful toolsets for process control and data fitting, fast and easy user interface construction, and an efficient code execution environment [21, 22].

3. Methodology

The construction concept brief of a cactus pear automatic guided vehicle that can detect Dactylopius Opuntiae is that it should be able to navigate from plant to plant using processed 3D data from and Microsoft Kinect. Once the AGV has successfully navigated over the plant then digital cameras should acquire images of the leaf pads. It would then convert the RGB to Hue and extracts only the relevant leaf pads Hue of green. This threshold image is then used to generate an RoI mask to extract the leaf pads from its background environment. Thereafter a grayscale threshold is done on the masked image to calculate the number and size of white dots (which is an indication of Dactylopius Opuntiae infestation) using particle analysis. The system is evaluated in a lab environment to determine specifications and the requirements of the SMART cactus pear farm.

3.1. Construction of AGV

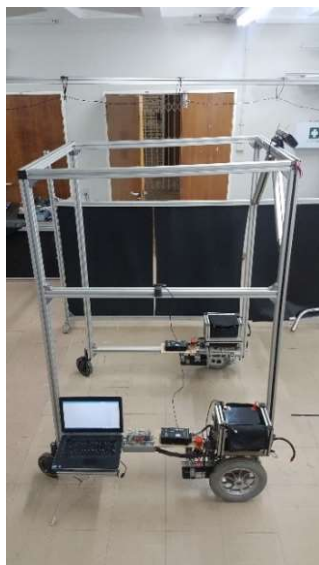Figures 1 and 2 below show the side and front view of the constructed AGV.

Figure 1. Side view of the AGV with the front to the right

Figure 2. Front view of the AGV with chair for scale.

Mobility is achieved with two 24 Volt 450 DC motors that are controlled using two SC Ass 70 10 controllers. The controllers get control signals from an NI myDAQ via the application as written in LabVIEW. Power is sourced from two 12V 40Ah connected in 24V. The Xbox Kinect is situated in the center, top, front and middle of the chassis that is constructed from aluminum profiling. The digital camera is mounted on the side, so as the AGV drives over the plant it can acquire a close-up image to check for infestations.

3.2. Navigation

The Microsoft Kinect sensor gives a 640 by 480 3D depth map array with each cell representing a distance value. This map is captured in LabVIEW as an image. Threshold is supplied to the image that converts the distance reading into a binary image that would indicate the presence of object (the plant) in the path. Image processing on the binary image includes erosion for small particle removal followed by a fill hole function. Particle analysis is calculated which gives area and center point of mass of blobs. The largest area blob is determined and its center point of gravity X Y coordinates is given to the mobility algorithm.

The movement algorithm is defined using state machine logic, with six different states:

- Straight forward: The center of mass X Y coordinates is in the center areas of the image. Motor controller right analogue -0.5 value that is connected via the NI myDAQ and motor controller left analogue -0.5 value that is connected via the NI myDAQ

- Slow left: The center of mass X Y coordinates is in the upper left corner of the image. Motor controller right analogue -0.45 value that is connected via the NI myDAQ and motor controller left analogue -0.35 value that is connected via the NI myDAQ

- Sharp left: The center of mass X Y coordinates is in the lower left corner of the image. Motor controller right analogue -0.35 value that is connected via the NI myDAQ and motor controller left analogue -0.45 value that is connected via the NI myDAQ

- Slow right: The center of mass X Y coordinates upper right corner of the image. Motor controller right analogue 0.45 value that is connected via the NI myDAQ and motor controller left analogue -0.45 value that is connected via the NI myDAQ

- Sharp right: The center of mass X Y coordinates lower right corner of the image. Motor controller right analogue -0.45 value that is connected via the NI myDAQ and motor controller left analogue 0.45 value that is connected via the NI myDAQ

- No object stop. Motor controller right analogue 0 value that is connected via the NI myDAQ and motor controller left analogue 0 value that is connected via the NI myDAQ

3.3. Dactylopius Opuntiae detection

An HD camera is connected to the side of the AGV chassis to acquire images as the plants move past. An RGB image is acquired every 400 milliseconds. This image is processed by extracting hue color plane. The Hue image is threshold with the green range of the leaf pads. The binary image result is particle analyzed with significant areas then used to generate a masking bounding rectangular RoI. This RoI is then applied to a grayscale version of the acquired image. The result is only the leaf pads

extracted from its background. The masked grayscale image is threshold, the binary image is eroded and holed filed. Thereafter particle analysis is applied that gives the number of blobs and areas (white spots as threshold). The significant area and amount would indicate Dactylopius Opuntiae infestation.

4. Results

The construction of Automatic Guided Vehicle that detects Dactylopius Opuntiae in Cactus Pears started with designing and building a chassis where the plants passes underneath it. 3D mapping was done for navigation. The detection of Dactylopius Opuntiae was done with image processing from side mounted digital cameras.

4.1. AGV construction

The chassis construction of proving makes it modular and reconfigurable. The chassis of the AGV that cross over the plants means that one can add robot arms on all sides and on top as upgrades. A drawback of the wheels used is that it would need paving at each side of the plant to minimize slipping or tracks need to be fitted.

4.2. Navigation

The Microsoft Kinect does not operate in direct sunlight. The AGV, however, could be sent out at night that will also assist with consistent lighting source for the detection of Dactylopius Opuntiae subsystem. The results in the lab test indicated that SMART farms will need to be planted in a continuous S form, with the start and end in the same spot to make sure the AGV returns home.

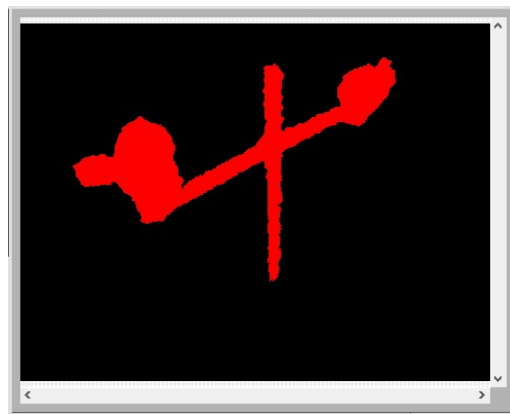**Figure 3.** Artificial constructed cactus pear plant for lab test.

Figure 4. Threshold binary image form 3D map.

Figure 4 shows navigation image processing where the result of the threshold binary and processed image of the object in figure 3. The center point of gravity is calculated with particle analysis and the largest area blob is then used to move the AGV with the movement state machine. It can navigate over a plant at speeds as indicated in Table 1.

Table 1. Motor controller signal transited to measured velocity.

Control signal	Velocity (ms^{-1})
-0.5	Forward 0.16
0.5	Reverse 0.16
-0.45	Forward 0.14
0.45	Reverse 0.14
-0.35	Forward 0.1
0.35	Reverse 0.1

The test also indicated that the second plant needs to be at least 1 meter away so that it comes into frame the moment the current plant moves under the chassis. If no object is detected, then the AGV will stop.

4.3. Dactylopius Opuntiae detection

As stated, the AGV will be sent out at night. Thus, the image acquisition could be done with a constant light source fitted on the chassis for Dactylopius Opuntiae detection
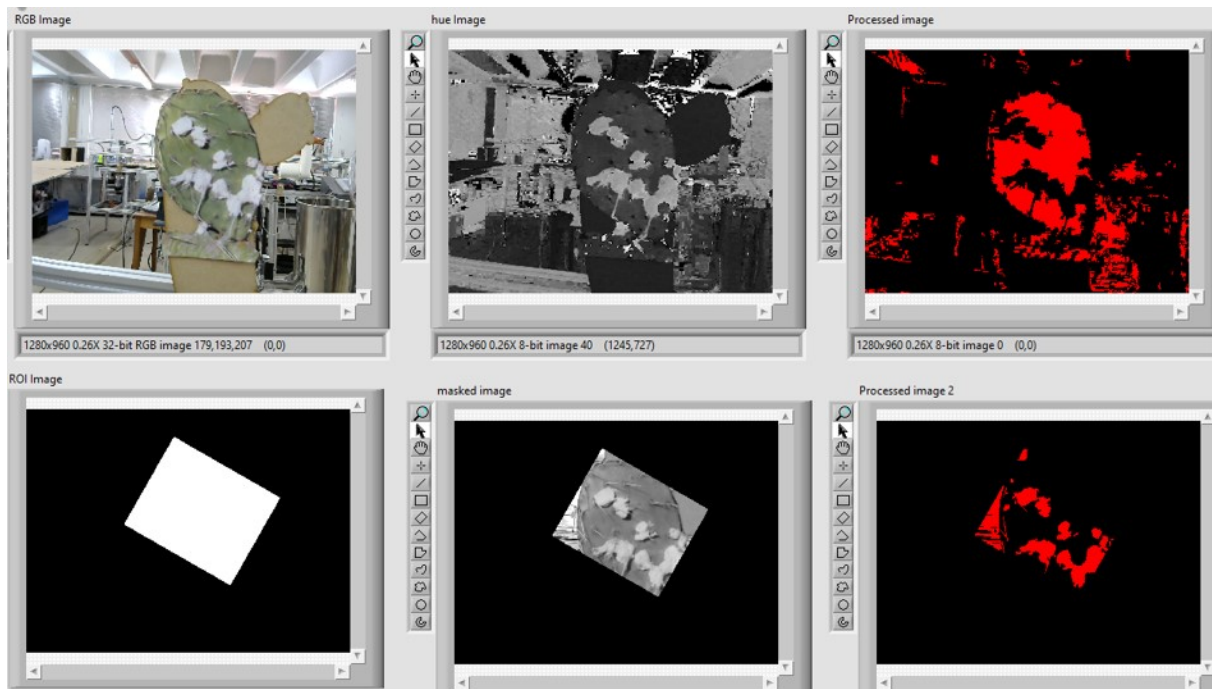

Figure 5. Infested leaf pad; This figure shows the RGB image (first row, first image) that is converted to HUE then only (first row, second image) the green extracted with threshold (last image, first row). From here the ROI is calculated to generate the masked (second row, fist image) that is applied over the grayscale converted image (middle image, second row) and lastly the threshold of this mask to show only the white spots (last image, second row).
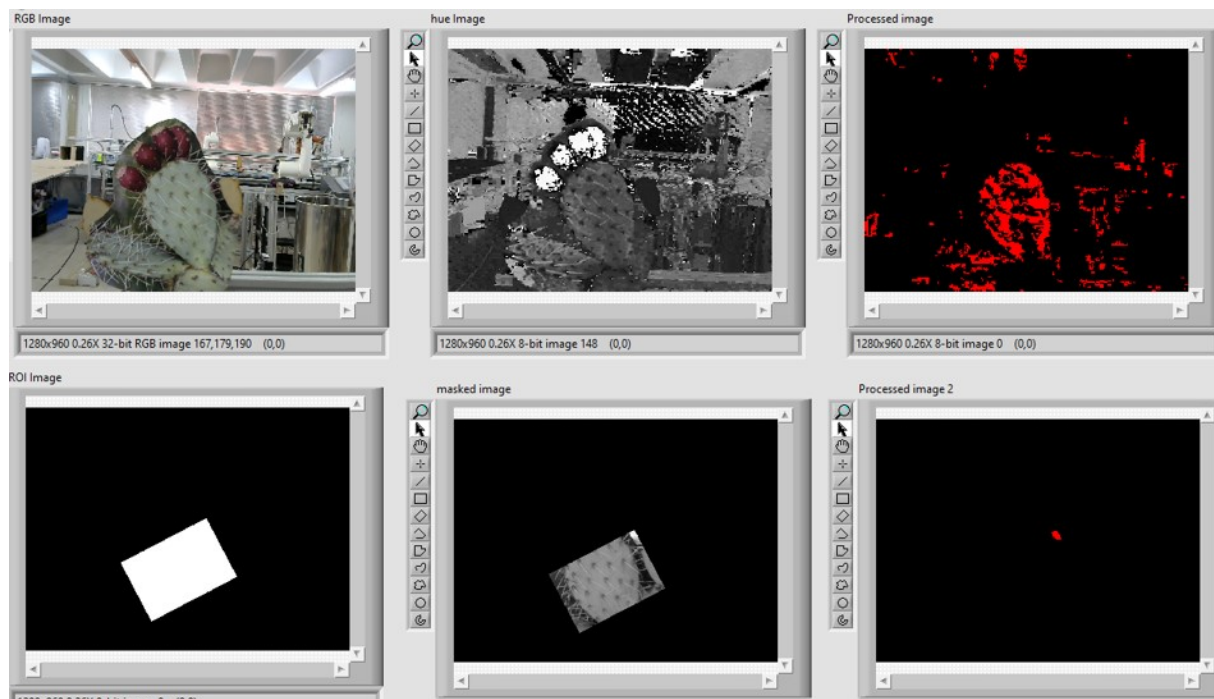
Figure 6. Healthy leaf pad; This figure shows the RGB image (first row, first image) that is converted to HUE then only (first row, second image) the green extracted with threshold (last image, first row). From here the ROI is calculated to generate the masked (second row, fist image) that is applied over the grayscale converted image (middle image, second row) and lastly the threshold of this mask to show only the white spots (last image, second row).

Figures 5 and 6 show the image processing steps as explained to generate the ROI and a binary image that is used in the particle analyses to calculate the area and number of white spots. Compare the processed last image in the second row of figure 5 and figure 6. Note that the infested one would/and do give more blobs from the particle analysis, indicating the infestation.

The same hue processing could be done to do fruit detection with the hue threshold at the fruit color
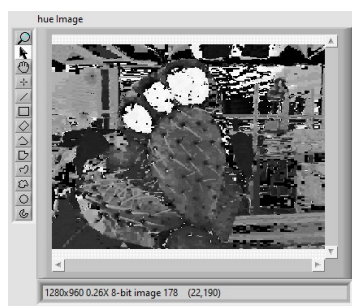

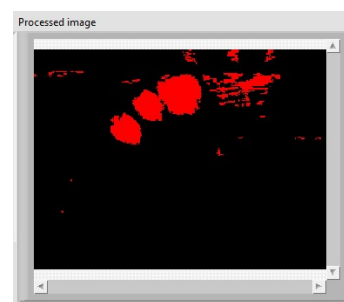**Figure 7.** Hue image of a leaf pads with fruit.

Figure 8. Threshold image for fruit detection

Figures 7 and 8 show hue threshold processing on the fruit color. An added advantage of hue processing is the ability to do fruit detection. This could be used to pick or inspect the fruits when particle analysis is done.

5. Conclusion

The purpose is to demonstrate a Farming 4.0 AGV that could be used detect Dactylopius Opuntiae. This paper demonstrates the construction using reconfigurable profiling of a chassis using DC motors and motor controllers with 24V rechargeable batteries. The motor controllers are controlled by application running on a computer that gives control signals to the motor controllers via NI myDAQ. Navigation is accomplished with image processing form the 3D map and translated into a movement state machine. Dactylopius Opuntiae detection is done with image processing from a digital camera. It is still uncertain what the reliability of the AGV would be in the harsh arid environment. The impact should be less since the AGV would only be sent out at night. The SMART cactus pear farm should for this application have paved ways on both sides of plants and the plants need to be planted not more than one meter form one another. It should also be planted in an S formation with beginning and end at the charging spot. Upgrades could be solar panels so that the AGV could recharge during the day at its last stop. Arms and pickers could be fitted to actively remove infestation or fruit picking. An internet of things could be installed to give the GPS location for the infested plant. SMART cactus pear farming would mean that food and feed could be produced in arid and semiarid environments. An AGV that detects Dactylopius Opuntiae would make sure that whole crops are not lost, which not only have a financial impact but also an impact on food security in drought areas. It might be that in the future automated cactus pear farming might be done on arid planets.

6. References

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