Simulation of Weed Detection and Spraying

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Introduction

Usage of autonomous vehicles for agriculture not only provides a solution to tackle the pressing problem of labour shortage, but also improvement in precision of operations such as weeding, harvesting and ploughing [1]. Precise weed detection is important to reduce over-spraying of herbicides onto crops and unseeded soil. Efficient spraying techniques are equally important to carry out the task of spraying given the information about weed positions. In this research a simulation of weed detection and spraying, along with an evaluation of the techniques used, are provided through the ROS using a simulated version of Saga Robotics 'Thorvald', an autonomous agricultural robot.

Methodology

Plant detection was done using colour masks in combination with morphology for three different crops. In the case of cabbage, folded leaves cause a variety of colours to exist. Therefore, only parts of the plant could be detected, without falsely classifying them as weeds. Holes in the lettuce were fixed with a series of erode and dilate operations. For onions, the crops and weeds were of similar colours, therefore colour masks had to be followed with Hough transforms to find the onion rows and mark them as a no-spray zone. The erode operation with 1D-vector as kernel was used to remove vertical onion leaves from the weed mask (See Figure 1).

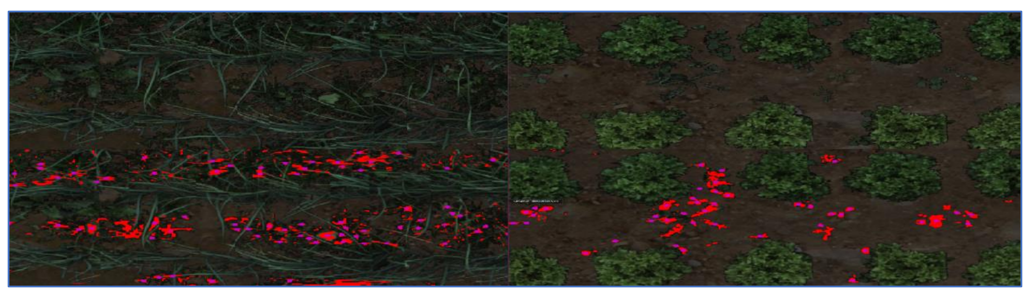

Fig. 1. Examples of input and output pictures for the weed detection system. Red shows contours of weeds, while purple shows a point to spray.

The mapping process is carried out before image processing. When a new frame from the camera is published, the timestamp of the image is used for finding a transform between systems of coordinates. If the image is not current enough for ROS to find a transform, the frame is dropped, due to high frame rate. The process is resumed after getting points from discriminators. These are then projected to points in the camera's frame and transformed to "world" frame with pre-computed transform. There is no effect of image processing time on the final map. Example result can be seen on Figure 2.

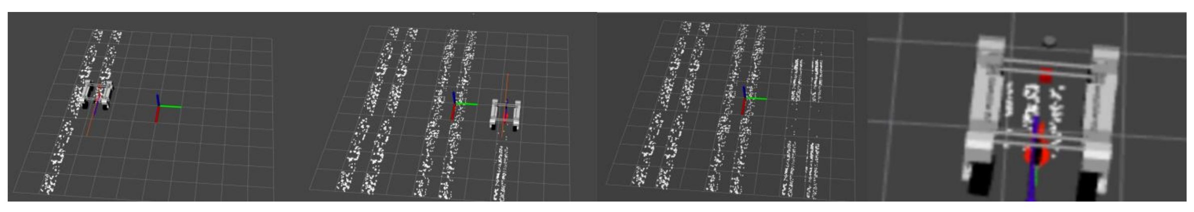

Fig. 2. Picture capturing various stages of the map creation process.

The most popularly used spraying technique is with multiple nozzles spread across a beam, which uses the nozzle closest to a detected weed for spraying. The disadvantages of this method are the presence of weeds beyond reach of any of the nozzles and over-spraying into crops due to large spraying radius [2]. The idea for a novel actuated precision sprayer with one degree of freedom that enables precise reach and reduced spraying radius is implemented in ROS and its performance is studied and compared with that of multiple nozzles (see Figure 3).

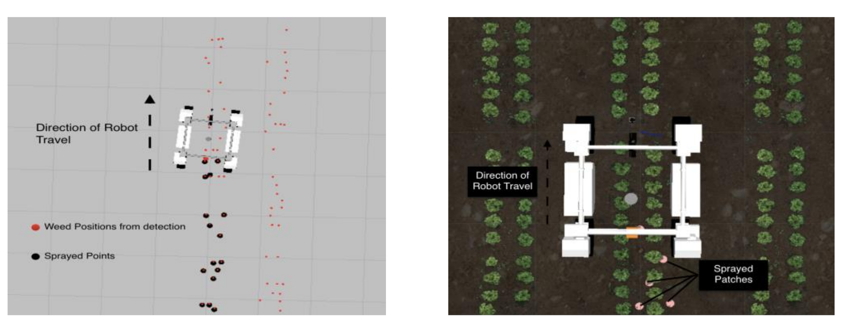

Fig. 3. Simulation of Actuated Precision Spraying in RViz (left) and Gazebo (right).

Evaluation & Results

Evaluation of the plant detection was done by manually counting the number of weed leaves which produced a spray point versus those which did not. The exact numbers are provided in Table 1.

	Detected as Weeds (young lettice)	Detected as Crops (young lettice)	Detected as Weeds (grown lettice)	Detected as Crops (grown lettice)	Detected as Weeds (anions)	Detected as Crops (anions)
Weeds	48	7(4)	33	7(3)	about 50	about 50
Crops	0	9	0	10	13	about 200

Table 1. Confusion matrix for weed detections for three crops. Numbers in brackets are the errors caused at stage of assigning the point.

The performance of the actuated precision sprayer was evaluated with respect to the three critical parameters: robot speed, spraying patch size and sprayer speed. The results indicate that increasing the robot speed results in decreased accuracy of spraying (see Table 2). This is quite intuitive as the higher robot speeds lead to situations where the sprayer misses some weeds due to the inherent delay associated with each spraying operation. Increasing the spraying radius of individual nozzles results in better coverage of weeds but also additional spillage onto crops (see Table 2). The optimal value is a trade-off between these two factors. The third test of varying the speed of the sprayer is calculated theoretically and the results are discussed in comparison with that of an alternate system comprising of multiple nozzles. We compare the spraying coverage of both solutions by varying the sprayer speed and simulated number of nozzles (see Figure 4). It is to be noted that~80% of coverage is reached for a system with linear sprayer speed of 5 m/s, which is achievable in terms of equipment design with standard servo motors. A similar result is achievable with a system comprising around 15 nozzles for a robot width of 1 m. With the proof of satisfactory performance, the design idea for an actuated sprayer system can be argued to be better than a multiple-nozzle boom sprayer because of the scalability of the design irrespective of the robot size. Also in more precise applications requiring a smaller sprayer radius, the performance of the actuated sprayer would be unchanged, while that of the multiple nozzle would reduce drastically.

Robot Speed	Weed Sprayed	Crop Sprayed	Spray Radius	Weed-Sprayed	Crop-Sprayed
0.5 m/s	86.25%	32.50%	2.5 cm	75.62%	8.21%
1.0 m/s	45.41%	16.50%	5.0 cm	82.40%	15.04%
1.5 m/s	33.75%	9.50%	10.0 cm	96.02%	33.08%

Table 2. Percentage of Weed and Crop Sprayed for varied Robot Speed and Spray Radius

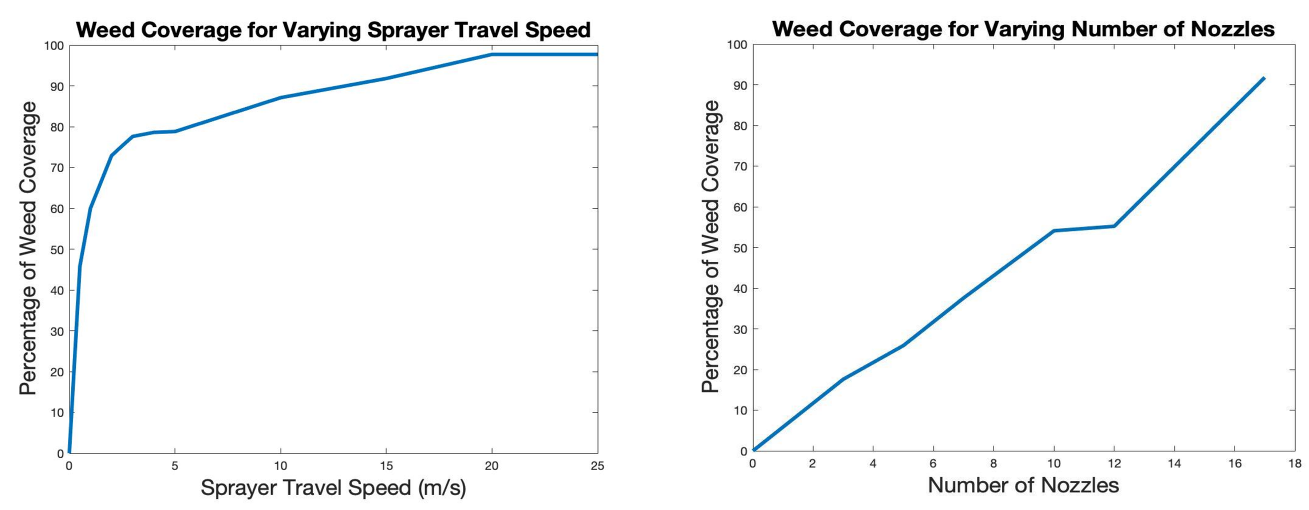

Fig. 4. Performance of Actuated Precision Sprayer (left) Vs Multiple Nozzle Sprayer (right).

Discussion

The weed detection discussed has severe limits, like struggling when crops and weeds are of similar colour. Moreover, adaptation for new crops or fields require a re-design of the algorithm from scratch.

The current solution for selective spraying, while allowing for high precision and flexibility using a linear actuator, required very accurate mapping of weeds and delivery of the herbicide. The focus of our work is on spatially accurate delivery of the weed eradication methodology, but is not limited to the specific precision spraying design and can be utilised more generally for delivery of precision interventions, allowing for even more targeted delivery and minimised impact on neighbouring crops (e.g. laser-based weeding).

References

[1] Gilbert, N.: Case studies: A hard look at gm crops. Nature 497 , 24–26 (2013)
[2] de Soto, M.G., Emmi, L., Perez-Ruiz, M., Aguera, J., de Santos, P.G.: Autonomous systems for precise spraying – evaluation of a robotised patch sprayer. Biosystems Engineering
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