A METHOD FOR SAMPLING SCAB SPOTS ON APPLE LEAVES IN THE ORCHARD USING MACHINE VISION

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ABSTRACT

One of the largest threats in apple orchards is scab. Current procedures involve models based on weather data that predict the likelihood of scab attacks. Previous work in laboratory conditions suggests that it is possible to see scab in NIR and SWIR before the naked eye. This study investigated and demonstrated methods for sampling leaves on the trees in the field. It was found that it was possible to detect scab spots after 4 days of inspection, which is too late for curative spraying, but a mapping perspective is suggested, and the proposed spot detection algorithm may be useful for other pests and other crops.

Keywords: Precision horticulture. Disease mapping. Sensors. Machine Vision

INTRODUCTION

The most important disease in apple production is scab (*Venturia inaqualis*) that infects both leaves and fruits, and leads to severe production losses. The scab fungus overwinters in fallen leaves and in spring infects young leaves during periods of rain. Current scab protection strategies relay on biological models in combination with weather forecasts that predict the likelihood of scab attacks. In case of scab warnings, the orchard is sprayed with preventive pesticides and this typically happens 10-20 times per season. Using curative sprays that are applied up to 72 hours after the rain would greatly reduce the need for spraying since weather forecast are still very unreliable when it comes to predicting showers and many sprays are applied in vain. When scab attacks are visible by the naked eye after 9-12 days, it is too late for curative measures. There are machine vision systems that detect scab spots on apples after harvest, and few research results on early detection on leaves in laboratory conditions with NIR spectral bands in CCD and expensive InGaAs sensor ranges (Delalieuxa et al 2009 and Wennecker et al 2009). The goal for this experiment was to investigate how to inspect leaves while on the trees with CCD cameras, which could make it tangible to do automatic mapping of scab infections at an early stage where curative compounds may still control the disease.

While it it possible to image RGB and NIR with JAI 2CCD cameras and adapted RGB cameras (Rabatel et al 2014) we also attempt a stereo solution, which has the additional benefit to prove control data for a selective spraying.

This project was driven by demand from growers (fig. 1).

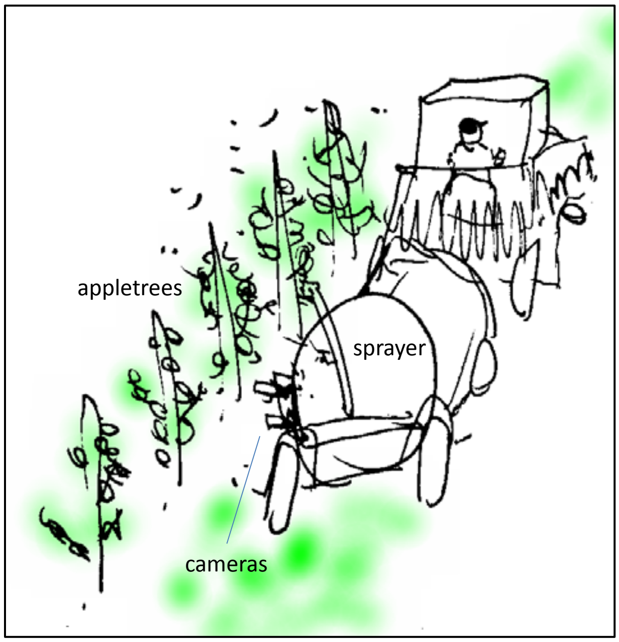


Figure 1. The concept that growers want.

METHODS

Nine untreated shoots were imaged before and after the model warned an almost certain infection. They were imaged 4 days after, which is the threshold for curative measures, and 12 days after where infection was visible to us. Three NIR/Red indices were compared for maximum contrast of scab spots; NDVI, MNDVI and RVI. Figure 3 shows results. Two Basler ACE 640-90GM cameras were used with 650nm bandpass filter (fig. 2) and polarizing filter on one and 850nm on the other. The polarizing filter was used to improve the correlation between the two color bands as the surface of a leaf is 5 times more specular reflective in Red than NIR (Berger et al 2010). In addition, the dynamic range in outdoor daylight was too large so three exposures were used to build HDR images (Deverek and Malik 1997). Correlation based stereo imaging has been successful before in orchards (Nielsen et al 2012) but when correlating red image with NIR image it was very noisy, so a two pass dynamic programming was used (Kim et al 2005). The 3D processing was done in three different ways (in order of descending magnitude of 3D reconstruction and CPU intensity): 1. Two pass Dynamic programming 3D reconstruction using the 2nd derivative of the images generated from laplacian of guassian transform. 2. Assuming the leaves existed in a plane that optimized the correspondence of edge features, where displacement is found by minimizing the correlation between images. 3. Manually panning through planes one by one and detecting leaf features in focus. After finding the depth of leaves the images from each camera was overlaid to produce index images. Figure 4 shows examples.

The image processing that segmented the image into leaves that were in focus to be inspected for spots was done in the Halcon image processing library by MvTec. The inspiration came from how human perception sees leaves. Eight different texture features were extracted and classified in a multilayer perceptron neural network classifier. See Figure 5. The training took 5 seconds but classification only took 20ms. (Laws, 1980) defined 7 different 1D texture masks, that can be combined into 49 different 2D texture masks. The 7 types of textures are "Level," "Edge," "Spot," "Wave," "Ripple," "Undulation," and "Oscillation. For leaf segmentation 6 were chosen: ee (2d edge),ss (2d spot),rr (2d ripple), ww (2d wave), le and el (combined level/edge in horizontal/vertical direction). The latter combinations is to represent edge of leaf/spot. The output form the texture laws was smoothed with 15x15 mean filter. The neural network was setup to take 6 inputs, reduce them to 4 in the hidden layer, normalize the inputs with principal component analysis. The result was cleaned up with morphology; Fill up holes, select objects larger than 25000 pixels, 25x25 closing operation and the connected component labelling, followed by 5x5 erosion in order to avoid edges.

Within regions classified as "leaves in focus" a simple spot detection was performed in Halcon using a large kernel smoothing filter, image subtraction and dynamic threshold.

A monocular approach with 590nm longpass filter on a color camera without NIR cut filter was also tested for the index images. The principle in this setup was that the blue channel represented the NIR and the red channel represented the red after a linear transform known as spectral sharpening.

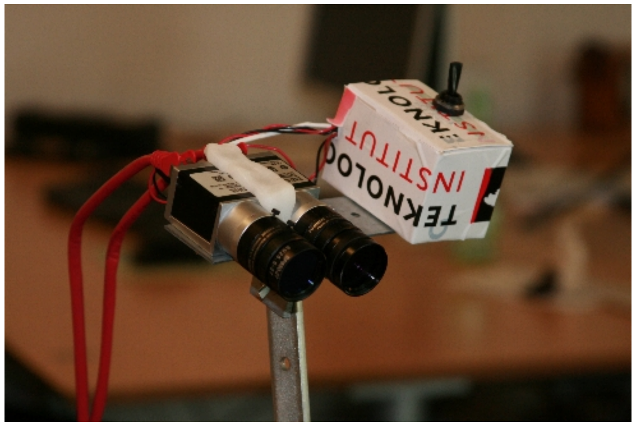


Figure 2. Two camera system with red plus polarizer filter on one and near -infrared on the other.

Figure 3. Images from adapted RGB camera. Comparison of indexes for best contrast of sick spots, from left to right: NDVI, RVI, MNDVI. The latter is best. (Note: The white parts under the leaves are shadows.)

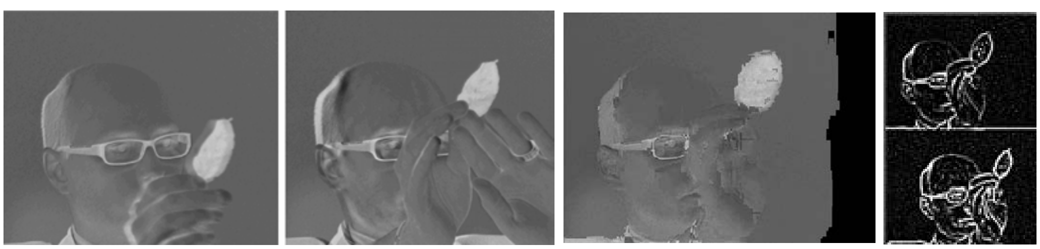


Figure 4. Comparisons of methods to overlay the Red and NIR channels. a-b) Plane shift. The algorithm seeks to bring objects in a certain distance in focus. Here it latched onto the face first and then the hands and leaf when both hands were held up making the depth the most prominent. c) Dynamic programming stereo vision, using the 2nd derivative of the red and NIR image (d).

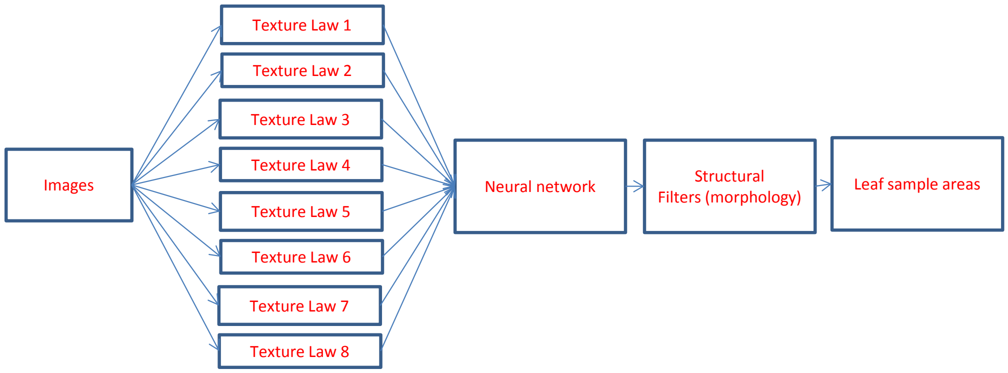


Figure 5. Procedure to segment leaves that are at the correct depth and in focus for inspection with inspiration from the human visual system.

RESULTS

The best index image was MNDVI because the spotless parts of the leaves were very uniform and the spots were dark. Full 3D reconstruction was noisy causing blurred leaf edges and spots in index image, making the plane based approach more reliable for texture classification and spot detection. With relatively few leaves in the image the automatic depth detection worked well, but in online orchard situations the panning method will be more reliable. Two out of nine leaves had infected spots in the images and were detected by the algorithm on the four-day threshold for curative treatment while it was still invisible to the naked eye. After 12 days it was certain that all nine shoots were in fact infected. The texture based segmentation succeeded in separating background such as sky, other rows, and grass from the leaves in focus and at the assumed depth plane and this made it possible to detect spots on the leaves. There were false positives in the edges of the leaves in a few cases. Future research is recommended on detection of these leaf edges so that these false positives can be rejected. Figures 6-8 shows examples of sick leaves.

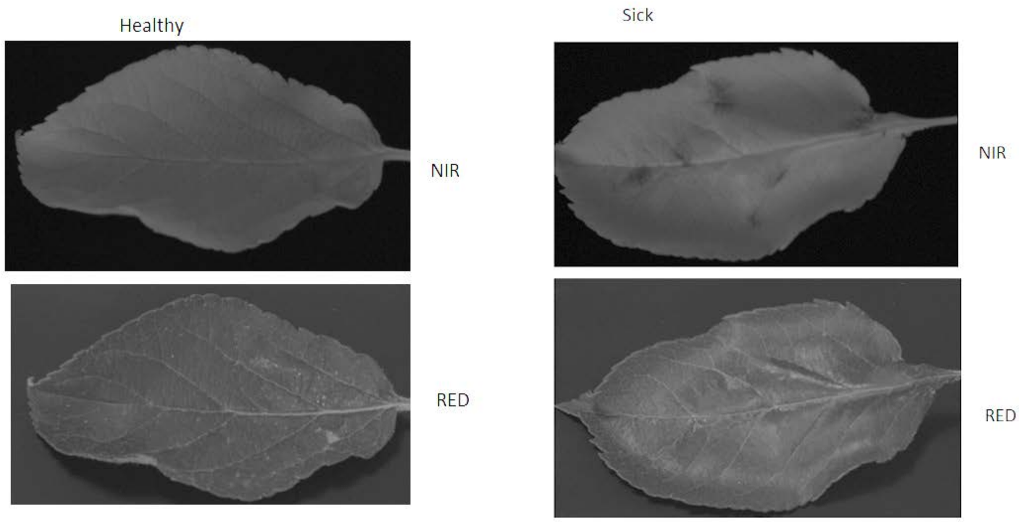
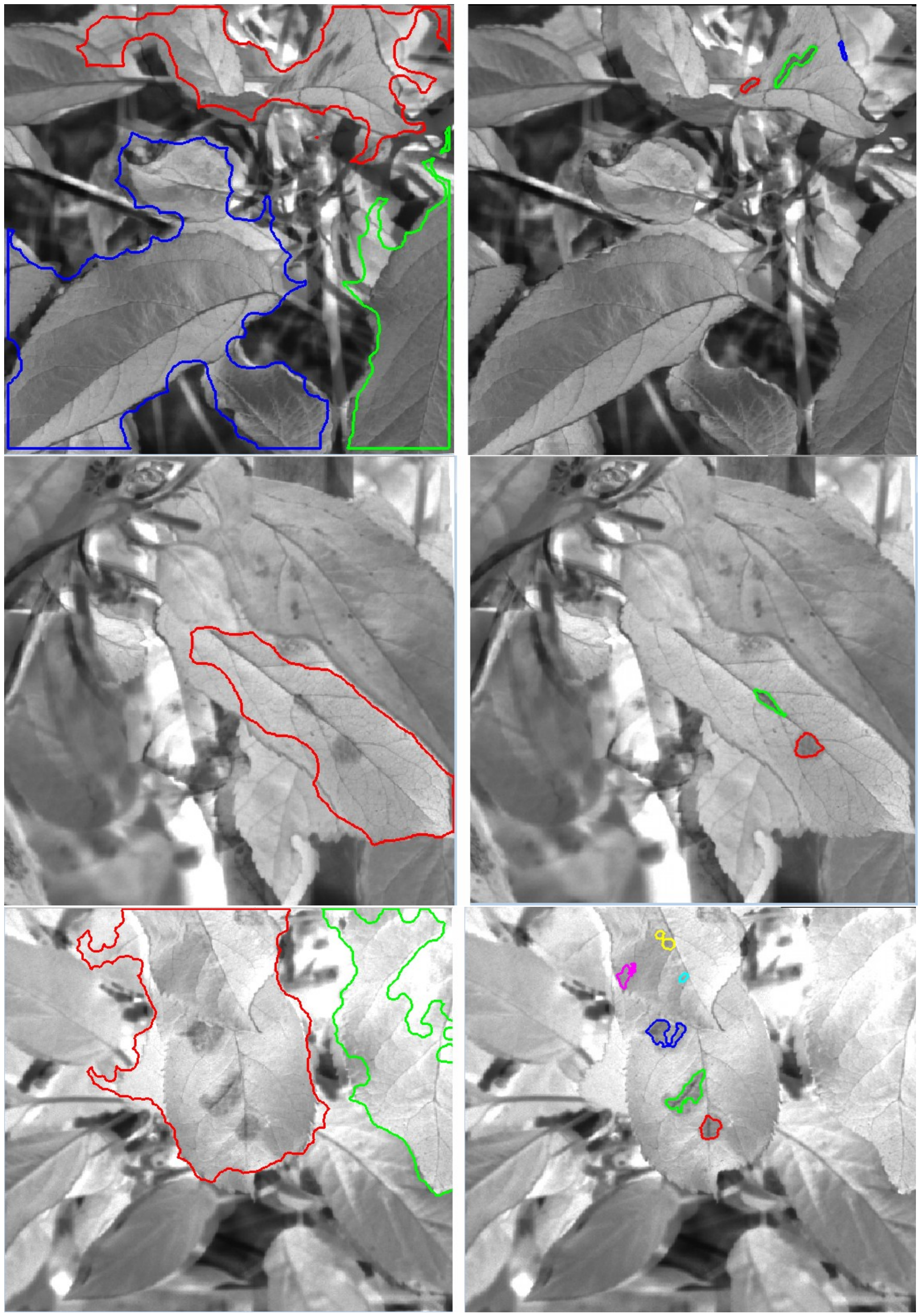


Figure 6. Images from healthy and sick leaves in red and nir channels.

Figure 7. Example of sick leaves that have no visible sign of infection after 4 days, but in NIR the dark spots start to show. Note the right leaf has an older infection that shows as brighter spots in the light. Two out of the infected nine shoots showed new dots in the NIR after 4 days, which is too late for curative spraying.



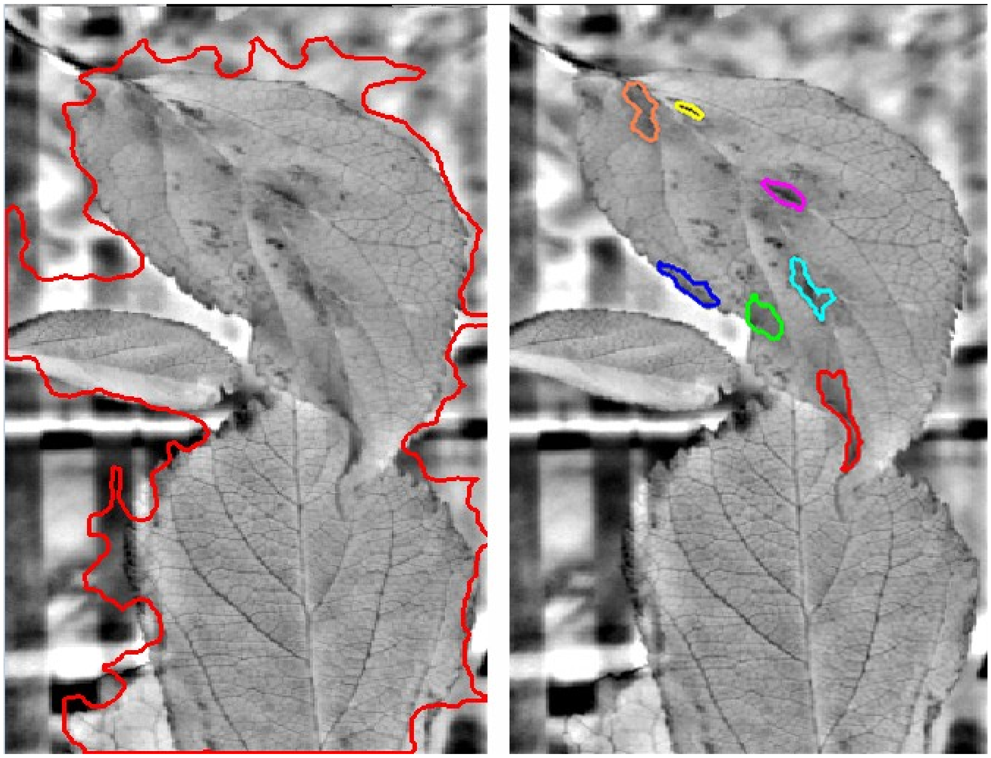


Figure 8. [left] Segmentation zones marked by the neural network classifier. Further refinement of leaf borders could be applied [right] Marked detected scab spots. Due to excessive filtering to avoid false positives at leaf borders smaller dots were not detected.

CONCLUSION

We demonstrated novel methods for spot sampling of leaves in real orchard conditions. While it was possible to detect spots before they were visible, only 22% of the infections were seen early enough for curative measures. It would be risky to assume that the system would always be able to detect at least one infection on an infected tree. The monocular based technology could be applied in automated mapping where the infection prediction could be improved for future infections. Furthermore, the sampling technology could be used for other pests where it could be detected early enough for treatment. Figure 9 propose the perspective of using the sampling for mapping the current state for future prediction of infection. Research should be carried out to make a safe spraying scheme based on this data.

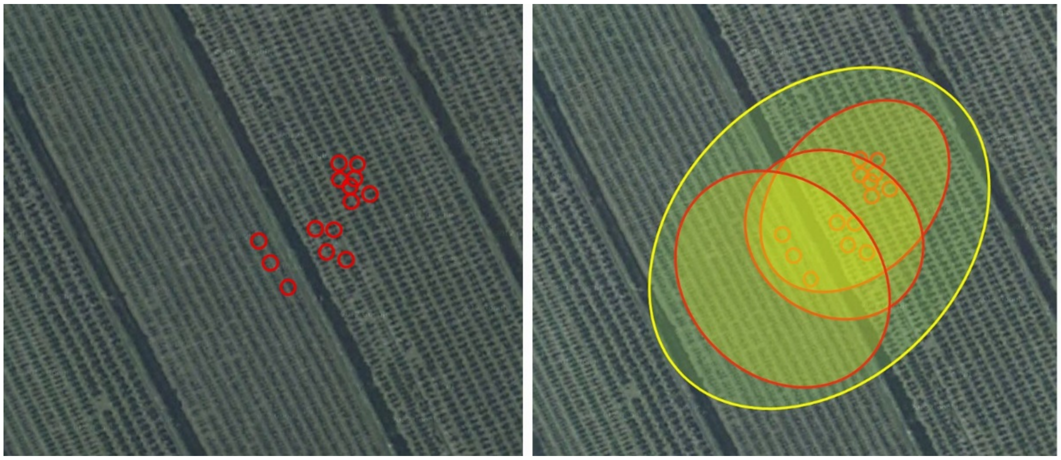


Figure 9. A GPS map could be updated when the vision system sees infections to be used with a mathematic model of the scab infection rates and weather data. The image shows an example where a vision module mapped infections and the model computed the risk of spread and inserted a buffer zone to spray.

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