Neural Network Machine Vision Identification of Plant Pathogens

Artificial intelligence (AI) is being used to accelerate the development of new disease resistant grape varieties. Funded by the USDA as part of the VitisGen2 research collaboration, the LRC is working with breeders and scientists to develop the next generation of grapes. A large part of the crossbreeding process is evaluating thousands of grape leaf samples for powdery mildew. After high-resolution, 46-megapixel images of sample leaves are taken, the AI system rapidly provides a quantitative measure of disease severity. Approximately 1600 samples can be evaluated in 8 hours.

The machine vision algorithm divides the 46-megapixel images into more than 800 smaller sub-images. Each sub-image is then evaluated for infection by a deep convolutional neural network (CNN) classifier. The CNN is an adapted version of the GoogLeNet neural network for putting web images into one of 1000 different categories that describe the image. In place of the 1000 output categories, the adapted network has two outcomes: infected or not infected. The severity of infection is then determined by the percentage of infected sub-images per leaf sample (Figure 1).

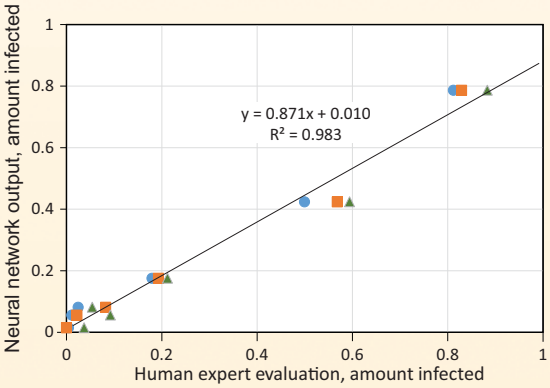

Figure 2. Comparison of the neural network determination of powdery mildew infection with that from three independent experts.

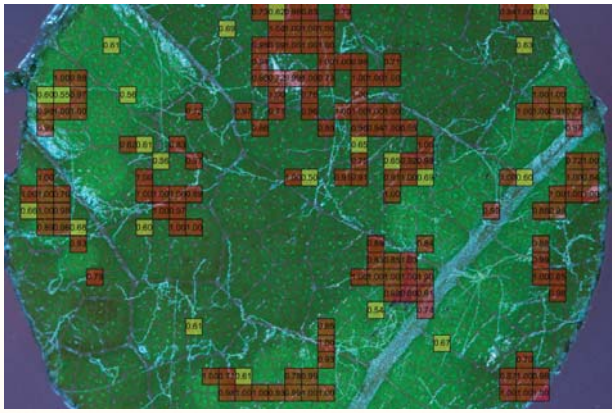

Figure 1. Analyzed leaf disk image. Positively infected sub-images are colored red, borderline cases in translucent yellow. 17% of the leaf image area is infected.

Performance validation

The accuracy of the machine vision was evaluated in several ways. Training the network on over 14,000 images of infected and disease-free leaf samples attained a 94% accuracy with a 2% false-positive rate. The trained machine vision algorithm results for a new, independent set of images was then compared to three expert human evaluators looking at the same images. Correlation of the human evaluators with machine vision ranged from 0.97 to 0.99 (Figure 2) depending on the evaluator, with roughly 90% agreement on which sub-images were infected or not. Lastly, leaf samples were imaged repeatedly over the course of 9 days to measure the growth of fungi. These time-series data offer new and more detailed information on disease resistance than previously available by traditional methods of assessment.

Conclusions

- Machine vision closely matches human observers for evaluating powdery mildew infection severity (0.98 correlation, 90% classification agreement).
- The throughput of machine vision is much faster than that of human observers.
- With faster throughput, the probability of finding improved grape phenotypes for disease resistance, taste and yield is greatly increased.

Sponsor

United States Department of Agriculture (USDA)

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