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Artificial intelligence could help farmers diagnose crop diseases

4 October 2016

Farmers in Africa. Credit: PlantVillage

A network of computers fed a large image dataset can learn to recognize specific plant diseases with a high degree of accuracy, potentially paving the way for field-based crop-disease identification using smartphones, according to a team of researchers at Penn State and the Swiss Federal Institute of Technology (EPFL), in Lausanne, Switzerland.

The technology could have particular benefits for producers in developing countries, such as in sub-Saharan Africa, who often do not have the research infrastructure or agricultural extension systems to support smallholder farmers, the researchers said.

"Global food security is threatened by a number of factors, not the least of which is plant diseases that can reduce yields or even wipe out a crop," said study co-author David Hughes, assistant professor of entomology and biology, College of Agricultural Sciences and Eberly College of Science, Penn State.

In addition, Hughes said, plant diseases can have disastrous consequences for smallholder farmers whose livelihoods depend on healthy crops. In the developing world, more than 80 percent of agricultural production is generated by smallholder farmers, and as many as half of hungry people live in smallholder farming households.

"Identifying a disease correctly when it first appears is a crucial step for effective disease management," he said. "With the proliferation of smart phones and recent advances in computer vision and machine learning, disease diagnosis based on automated image recognition, if technically feasible, could be made available on an unprecedented scale."

To begin to test this hypothesis, the researchers built a neural network, which is a large cluster of computers with graphical processing units. Using a deep-learning approach—an emerging area of machine learning that uses algorithms to model high-level abstractions in data across multiple processing layers—they fed more than 53,000 images of diseased and healthy plants into the network and trained it to recognize patterns in the data.

The research builds upon tremendous improvements in the past few years in computer vision, and object recognition in particular, said co-author Marcel Salathé, associate professor and head of the Laboratory of Digital Epidemiology, EPFL.

"Neural networks provide a mapping between an input, such as an image of a diseased plant, to an output, such as a crop-disease pair," he explained. "Deep neural networks recently have been applied successfully in many diverse domains. These networks are trained by tuning the network parameters in such a way that the mapping improves during the training process."

As an example of how this emerging technology works, Hughes cited the way Facebook can identify a user by analyzing an uploaded photo.

"These algorithms can classify complex phenotypes, such as recognizing a face," he said. "Our goal is to use them to identify plant diseases."

The images used in the study were part of a public-access archive of photographs contained in PlantVillage, a free, online plant-disease library and database Hughes and Salathé developed in 2012. The data set depicted 14 crop species—both healthy and with disease symptoms—and 26 diseases. Each image was assigned to one of 38 classes, each representing a crop-disease pair, and the researchers measured the performance of their model in placing images into the correct class.

"Our goal was to classify crop species and the presence and type of disease on images that the model had not seen before," said lead author Sharada Mohanty, doctoral researcher in biotechnology and bioengineering, EPFL. "Within the PlantVillage data set, the model achieved an accuracy rate as high as 99.35 percent, meaning it correctly classified crop and disease from 38 possible classes in 993 out of 1,000 images."

Mohanty noted that building the algorithms and training the model require significant computing power and time, but once the algorithms are built, the classification task itself is very fast, and the resulting code is small enough to easily be installed on a smartphone.

"This presents a clear path towards smartphone-assisted crop-disease diagnosis on a massive global scale," he said.

Hughes noted that in addition to assisting growers in developing countries, the technology has great potential in a developed-world setting. "This could be a tool for land-grant extension personnel at public institutions as they assist their grower clients, as well as for the legions of backyard gardeners who want to identify what is harming their produce," he said.

The researchers pointed out online in *Frontiers in Plant Science* that this approach is not intended to replace existing solutions for disease diagnosis, but rather to supplement them.

"Laboratory tests ultimately always are more reliable than diagnoses based on visual symptoms alone, and early-stage diagnosis only by visual inspection often is challenging," Hughes explained. "Nevertheless, given the expectation that more than 5 billion smartphones will be in use around the world by 2020—almost a billion of them in Africa—we do believe that the approach represents a viable additional method to help prevent yield loss. With the ever improving number and quality of sensors on mobile devices, we consider it likely that highly accurate diagnoses via the smartphone are only a question of time."

More information: Sharada P. Mohanty et al. Using Deep Learning for Image-Based Plant Disease Detection, *Frontiers in Plant Science* (2016). DOI: 10.3389/fpls.2016.01419

Provided by Pennsylvania State University