Chapter 32
Cell Phone Image-Based Plant Disease Classification

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ABSTRACT
Modern communication and sensor technology coupled with powerful pattern recognition algorithms for information extraction and classification allow the development and use of integrated systems to tackle environmental problems. This integration is particularly promising for applications in crop farming, where such systems can help to control growth and improve yields while harmful environmental impacts are minimized. Thus, the vision of sustainable agriculture for anybody, anytime, and anywhere in the world can be put into reach. This chapter reviews and presents approaches to plant disease classification based on cell phone images, a novel way to supply farmers with personalized information and processing recommendations in real time. Several statistical image features and a novel scheme of measuring local textures of leaf spots are introduced. The classification of disease symptoms caused by various fungi or bacteria are evaluated for two important agricultural crop varieties, wheat and sugar beet.

INTRODUCTION
In the presence of increasing environmental challenges such as water scarcity, climate change, concerns about food supply, safety and the reduction of adverse environmental impacts, sustainable agriculture is an extremely important resort to cope with a rapidly growing world population. The scope of farming that is sustainable outreaches short-term yield maximization and efficiency steered exploitation of resources. Instead the focus lies on farming methods that secure long-term yields of products satisfy-
Cell Phone Image-Based Plant Disease Classification

In the food and fiber needs of animals and humans while enhancing the quality of the environment. One important way to achieve this goal is to control the outbreak and spread of plant diseases causing significant reduction in the quantity and quality of farming products. Accordingly, it is crucial to apply targeted rather than broad and overdosed preventive control to minimize soil and water damage. Targeted disease control, however, relies on two major requirements. First, plant diseases need to be identified reliably, even for early stage outbreaks. Second, the information has to reach crop producers and farmers promptly, especially in remote areas that are difficult to access by experts. The approach presented in this chapter aims to achieve both requirements, accurate plant disease classification and real-time forecast based on the particular state in the field.

In addition to providing farmers with treatment recommendations, accurate plant disease classification is also pivotal in order to monitor the outbreak and spread of diseases. This information can then again be used to predict yield losses and to forecast the temporal and spatial disease spread facilitating the coordination of countermeasures. While there exist many methods to classify plant diseases as for instance molecular techniques, non-invasive approaches such as visual assessment, are more favorable. Modern techniques of visual disease assessment are based on digital photography combined with image analysis (Bock, Poole, Parker, & Gottwald, 2010; Camargo & Smith, 2009a) or hyperspectral imaging (Rumpf et al., 2010; Liu, Wu, & Huang, 2010). Visual image analysis also contributes to the understanding of biological processes such as the molecular mechanisms of photosynthesis (Rascher, Nichol, Small, & Hendricks, 2007) or the growth rate and spread of symptoms on the disease carrier (Duncan & Howard, 2000; Rossi et al., 2000).

Nowadays advances in cell phone technology, data storage and transmission, as well as network coverage allow smart phone users to communicate almost any kind of information in real time from anywhere, such as images taken with the built-in camera. Further, efficient and accurate pattern recognition approaches are able to extract and process information encoded in image data in order to retrieve information about its content in real time. It is therefore not difficult to imagine an app that automatically applies face detection and annotates a picture of a group of friends taken with a smart phone (Ng, Savvides, & Khosla, 2005; Hadid, Heikkilä, Silvén, & Pietikäinen, 2007). The image could then instantly be posted on a social network platform or sent to the persons it contains. Unfortunately, equivalent services are not available for agricultural application scenarios.

Whereas “passive” information systems providing farmers with instructions on how to identify major plant diseases are available as smart phone applications, it is not possible for a farmer to get instant personalized feedback on the actual state of the plants in his field. Our goal is to develop a system to solve the specific problem of disease classification based on plant cell phone images. Mobile devices such as smart phones equipped with cameras provide the technical opportunity to achieve this goal. However, new challenges arise for image processing and analysis. These challenges are due to the fact that implementations of image processing algorithms on a cell phone have to comply with particular characteristics such as constrained battery life, restricted computational power, or limited bandwidth. The work reported here results from a project on using cell phone images in an agricultural scenario, where farmers take pictures of plants they suspect to be infected by a disease such as shown in Figures 1 and 2. Information extracted from the images is then sent to a central server and analysis results are supposed to be reported back to the farmer while still in the field. In this setting, efficient and reliable image analysis is pivotal. Given the weak connection strengths out in the fields or the increased fees for high volume data transfer, it is hardly possible to transmit several pictures of sufficient resolution. If, on the other hand, the extraction of regions of interest or even the feature computation were performed
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