Chapter 52
Plant Classification for Field Robots:
A Machine Vision Approach

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ABSTRACT

Small size agricultural robots which are capable of sensing and manipulating the field environment are a promising approach towards more ecological, sustainable and human-friendly agriculture. This chapter proposes a machine vision approach for plant classification in the field and discusses its possible application in the context of robot based precision agriculture. The challenges of machine vision in the field are discussed at the example of plant classification for weed control. Automatic crop/weed discrimination enables new weed control strategies where single weed plants are treated individually. System development and evaluation are done using a dataset of images captured in a commercial organic carrot farm with the autonomous field robot Bonirob under field conditions. Results indicate plant classification performance with 93% average accuracy.

INTRODUCTION

Agriculture today is dominated by large and heavy machines that operate with high speeds to complete the farming task as quickly as possible. At this level of throughput large portions of the field and thus many plants are treated in the same way.

The current trend of automation and the emergence of robotic technologies in agriculture enable a shift from homogenous treatment of whole fields towards location specific farming. This includes a level where single plants or parts of plants (e.g. fruits, branches or leaves) are treated individually and get the specific care they require. Examples for such precision agriculture tasks are selective harvesting, single plant weed control and adaptive fertilization.

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One precondition for such automation including intelligent farm management as well as robotic precision agriculture activities is the availability of detailed information. This includes global data like weather and environment conditions, information on field level down to plant specific information like the phenotype of single plants. Such data serve as basis for a more automatic, precise, cost-effective and environmentally friendly agriculture.

When considering sensing technologies for plant data acquisition in the field, optical sensors like cameras combined with machine vision algorithms are promising. They enable capturing of information from field scale to individual plants or leaves. However, for characterization of individual plants or leaves in the field many approaches still lack the required precision, especially in cultures with very small plants and close-to-crop weed infestation.

When camera based sensing technologies are combined with autonomous field robots, tasks which are still done manually today or tasks which require individual treatment of plants can be automated. For example, close-to-crop weed control in organic vegetable farming is still a manual task for field workers due to high precision and organic cultivation requirements. The weed control process requires a lot of manpower, is very costly and crucial for good yields. Without weed control yield losses of up to 70% depending on the culture are possible (Slaughter, Giles, & Downey, 2008).

This chapter discusses how machine vision techniques can be applied to field images with the goal to extract information suitable for the automation of precision agriculture tasks. This enables development of phenotyping solutions like crop/weed discrimination, calculation of weed coverage ratio, counting of crop plants and the determination of inter plant spacing in the field.

Within the project RemoteFarming.1 (Bangert et al., 2013) one such precision agriculture use case is addressed in detail: A new version of the Bonirob field robot (Ruckelshausen et al., 2009) is developed together with an application module for single plant weed control in organic vegetable farming. Organic carrot farming is chosen as culture because there weed control is currently still performed manually and is one of the main expenses during cultivation. The detection of weed plants in carrot farms is difficult: weed and crop plants are small and approximately of the same size, weeds grow close-to-crop and there is overlap between plants.

The goal of the machine vision system is precise plant classification (Haug, Michaels, Biber, & Ostermann, 2014). This approach for plant classification does not require segmentation into individual plants or leaves. Crop and weed are discriminated based on features extracted from image patches generated from the image. The image patches overlap because the patch size is significantly larger than the spacing between the patch center points. Subsequently, machine learning is applied to discriminate different plants. The output of the system is a plant classification image where for every biomass pixel the plant type is predicted. Figure 1 displays a sample input image (on the left) with the final plant classification prediction image (on the right).

Field tests and data acquisition are performed with the autonomous field robot Bonirob in an organic carrot farm in Northern Germany. This ensures that the data acquisition scenario matches the application conditions of the system as closely as possible. During data acquisition the carrot crop plants are all in similar early true leaf growth stage. Weed plants however occur in more growth stages and can be smaller or larger than crop plants. This data is used to train and test the plant classification framework.

The evaluation of results indicates that the presented approach is able to successfully classify plants in this use case; plant classification performance with 93.08% average accuracy is achieved. The system can cope with the challenging situation of close-to-crop weeds and overlap of plants. It outputs a full plant classification image with per-pixel plant type predictions that is suitable for the considered single