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Research Paper

Region-based colour modelling for joint crop and maize tassel segmentation

Hao Lu, Zhiguo Cao*, Yang Xiao, Yanan Li, Yanjun Zhu

National Key Laboratory of Sci. and Tech. on Multi-Spectral Information Processing, School of Automation, Huazhong University of Sci. and Tech., Wuhan 430074, PR China

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Crop segmentation is a frequently occurring problem for computer vision applications in agriculture. Meanwhile, the fine-grained shape extraction of maize tassels is also an essential step in the detasselling and field-based phenotyping research. However, existing methods are usually dependent on category, which is hard to transfer to other cultivars with different colours. To address this, the goal of this study is to develop a general method that can process different colours simultaneously and that has good flexibility and expandability. Targeting maize, we proposed to segment jointly the crop and maize tassel. In particular, a novel joint segmentation dataset regarding crop and maize tassel (323 images with corresponding manually-annotated ground-truth images) is constructed, hoping that it can serve as a benchmark to facilitate related studies. Technically, a region-based approach that leverages the efficient graph-based segmentation algorithm and simple linear iterative clustering (SLIC) is developed to generate region proposals. Also, we proposed to model colours with ensemble neural networks specific to each intensity, aiming to achieve robustness to illumination. In addition, two simple but effective strategies are devised to accelerate the colour statistics extraction and ensemble model prediction. The effectiveness and efficiency of our method are demonstrated on the two segmentation tasks, respectively. Results show that our method significantly outperforms other state-of-the-art approaches on tassel segmentation, with average precision of 74.3%, and achieves comparable performance of 77.8% on the traditional crop segmentation even with the naivest colour feature. The dataset and source code are made available online.

1. Introduction

Crop segmentation is a fundamental issue for computer vision applications in agriculture. Many problems, such as crop growth stage prediction (Yu et al., 2013), crop row detection (Montalvo et al., 2012), density estimation (Steward & Tian, 1999), cover crop identification (Cruz-Ramírez, Hervás-Martínez, Jurado-Expósito, & López-Granados, 2012), leaf disease detection (Camargo & Smith, 2009), and crop biomass monitoring (Jannoura, Brinkmann, Uteau, Bruns, & Joergensen, 2015), greatly depend on the behaviour of crop

* Corresponding author.
E-mail addresses: poppinace@hust.edu.cn (H. Lu), zgcao@hust.edu.cn (Z. Cao), Yang_Xiao@hust.edu.cn (Y. Xiao), yananli@hust.edu.cn (Y. Li), yjzhu@hust.edu.cn (Y. Zhu).
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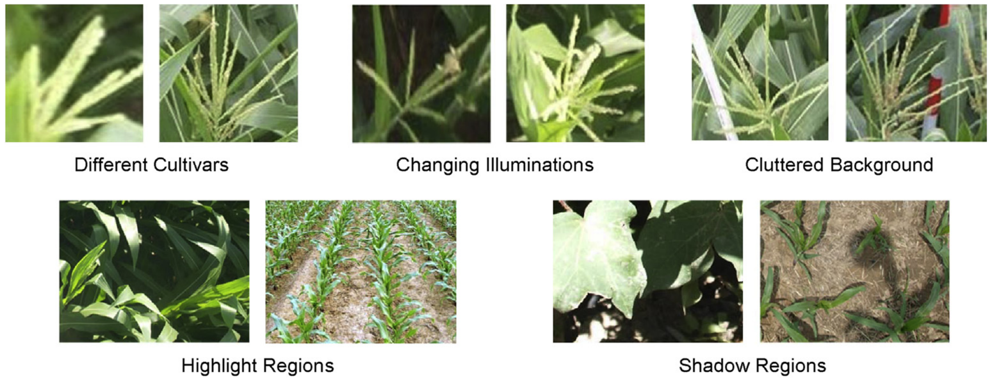

Fig. 1 – Challenges in the field-based crop and maize tassel segmentation. Images are rescaled for better view.

segmentation algorithm. Meanwhile, efforts have also been made to reveal the relationship between the tassel and crop growth status. For instance, Ye, Cao, and Yu (2013) uses the dynamics of maize tassel to predict the tasseling stage, Geraldi, Filho, and Vencovsky (1985) shows a negative correlation between the tassel branch number and final yields, and Lambert and Johnson (1978) point out that small tassel size can lead to higher yields. Recent advances in phenotyping research have also explored the feasibility of tassel trait characterisation (Lu, Cao, Xiao, & Fang, et al., 2015; Yang et al., 2014). In addition, the detection of maize tassels is also an important step for detasselling processes (Kurtulmuş & Kavdir, 2014). Automatic detasselling can potentially avoid self-pollination, keep the purity of seed genetics and reduce labour and time for manual operations. Similar to crop related studies, these attempts in maize tassel usually requires fine-grained shape extraction, which again becomes an image segmentation problem.

However, many existing segmentation methods developed for agricultural applications are usually intentionally designed for a specific cultivar. For example, crop segmentation methods often serve green crops. As will be shown in Sec. 4, there exists an apparent gap when transferring these methods to other non-green objects in agriculture. To address this, we intend to develop a general method that has enough flexibility and expandability. What we mean by *flexibility* lies in the ability of the method to tackle different colours simultaneously and *expandability* is used in the sense that one could incorporate more semantic labels into the model. In this work, we proposed to perform joint crop and maize tassel segmentation. Yet, joint segmentation is indeed a challenging problem in which one has to cope with various colour distributions brought by the cultivars, different illuminations caused by the weather, highlight and shadow regions, and the cluttered background of the natural canopy (e.g. weeds and stones), as shown in Fig. 1. Another notable challenge is that one often deals with high-resolution images in the scenario of agriculture, which potentially restricts the complexity of the algorithm. That is, an algorithm used in the real-world condition has to produce the result within a specific time.

In this paper, the joint segmentation is formulated as a semantic segmentation problem (Carreira, Caseiro, Batista, & Sminchisescu, 2012) in the sense that a region is deemed as belonging to a specific category only if it contains a semantic region of that category. Figure 2 shows our main technical pipeline. The proposed method mainly consists of two stages. That is, region proposals generation and colour model prediction. Concretely, the efficient graph-based segmentation algorithm (Felzenszwalb & Huttenlocher, 2004) and simple linear iterative clustering (SLIC) (Achanta et al., 2012) are first employed to generate region proposals, which has the effect of region-smoothing and edge-preserving. Next, each region proposal is passed to the neural network based ensemble models called neural network intensity (NNI) colour model, in order to attach semantic meanings of the crop, tassel or background to these regions. For efficiency, two simple but effective strategies are proposed for fast colour feature extraction and model prediction. In particular, a novel joint segmentation dataset regarding crop and maize tassel is constructed to evaluate the effectiveness and efficiency of our method. The experimental results show that our approach significantly outperforms other state-of-the-art approaches for tassel segmentation and achieves comparable performance on the crop segmentation. Also, our approach is somewhat attractive in computational efficiency. Therefore, we believe that the approach presented in this paper will be of great practical interest to the agricultural engineering community.

The contributions of this paper are summarised as:

- A region-based colour modelling method that integrates region proposals generation and ensemble neural networks is developed for joint crop and maize tassel segmentation.
- A joint segmentation dataset regarding crop and maize tassel is constructed and published online, in the hope that it can serve as a benchmark to facilitate related studies.[1]
- Two general and effective strategies are proposed to accelerate the computation of colour statistics and prediction of ensemble model.

The remainder of this paper is organised as follows. Sec. 2 briefly reviews the related work on the crop and tassel segmentation. Sec. 3 describes our dataset and method. The

[1] The joint segmentation dataset, highly vectorised Matlab source code of our proposition, as well as our implementation of the methods used for comparison are made available online at: https://sites.google.com/site/poppinace/.