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Application note

Rice and wheat grain counting method and software development based on Android system

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ABSTRACT

Thousand grain weight is the main component of rice and wheat yields, and an important indicator for variety breeding and cultivation management. Grain counting is an essential step for thousand grain weight measurement. Among several current counting methods, manual counting is laborious and time-consuming; electronic counting devices are expensive; the counting accuracy based on image segmentation processing is not high; and their uses are inconvenient. This study attempts to develop an application program (APP) for fast rice and wheat grain counting based on Android mobile phones for convenient use. The study identifies the relationship between image feature points and the number of grains, explores the measurement method of image feature points, and compares it with existing counting methods in terms of similarities and differences. The study also formulates grain counting calculations and develops an application program that is easy to operate. The high accuracy of this counting method has been demonstrated by tests of different varieties. The error ratio are below 2%. The program has a short running time. The counting time is generally less than one second (1 s) for no more than 400 seeds. The program is convenient and easy to operate. The counting and batch-processing operations are simple. In summary, the grain counting method built in this study can be used as an effective rice and wheat grain counting tool. This study also provides a reference for the development of application programs for grain counting of other kinds of crops.

1. Introduction

Grain weight is an important component of crop yields (Slafer et al., 2014). Crop yields largely depend on the number of grains per spike and the thousand grain weight (García et al., 2016). Therefore, thousand grain weight is considered an important parameter for the effective evaluation of cultivation measures and variety breeding (Li et al., 2005). It is a measurement indicator frequently used in crop research. Counting is the first step in the measurement of thousand grain weight. Common counting methods rely on manual counting (Liu et al., 2016), electronic counting devices (Mclaughlin et al., 1976), and image analysis technologies (Zhong et al., 2010). Manual counting is laborious and time-consuming. Human eyes may be tired and thus cause errors. Its accuracy cannot be guaranteed. Electronic counting devices count the breakpoints as grains pass through a laser (http://www.shuliyi.com/). This kind of equipment is expensive. The price ranges between $500 and $6000, depending on counting accuracy. The equipment is bulky and can only be used in stationary laboratories. The operation is cumbersome and complex. The cost of grain counting through image analysis technologies is lower. The grain recognition algorithm is the key to counting accuracy when applying these technologies.

Grain counting based on image analysis is realized mainly in two steps. Images are segmented, and grains are separated from the image background. The number of grains is then calculated in each region. The two steps are the keys to grain counting. Researchers have designed a large number of touching-grain separation algorithms, including the dilation and erosion method (Shatadal et al., 1995), the watershed algorithm (Bleau and Leon, 2000), the active contour model (Chou and Wang, 2004), and feature point matching (Hobson et al., 2009; Kiratiratanapruk and Sinthupinyo, 2010; Lin et al., 2014). The erosion and dilation method is the most basic algorithm in mathematical morphology. It identifies geometric boundary lines by adopting a strategy of first separating through erosion and then restoring through dilated of overlapping areas. The method is simple. The frequency of erosion and dilation are determined by human experience. But this method cannot achieve accurate separations for large touching areas, and the unrepeatability of corrosion and expansion could cause errors. The watershed algorithm is a widely-used separation method that

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uses local gradient differences in overlapping areas and identifies dividing lines through a simulation process of water flooding, starting from seed areas under the pixel gradient constraints. The major deficiency of the traditional watershed algorithm is over-separation. Recently many scholars have conducted studies to improve the watershed algorithm to reduce over-separation (Duarte et al., 2006; Wang and Paliwal, 2006). The active contour model is a classical image segmentation algorithm based on partial differential equations (Zheng et al., 2009). It locates contours of crop grains by setting curves (Yang et al., 2010). But the separation results depend on the selection of initial curves. Feature point matching detects feature points in grain-touching areas using methods such as curvature detection and corner detection, and processes the grain separation through feature point matching (Bai et al., 2009). This method generally has high separation accuracy. But it has matching errors for complex touching.

In terms of support equipment, grain separation or counting based on image analysis is mostly performed on a computer terminal (Mebatsion and Paliwal, 2011). The operation is not very convenient. With the large-scale popularization of mobile Internet, the industry of mobile intelligent terminals has undergone dramatic changes. Android mobile phones have significantly changed the way of living and people's behaviors (Ongtang et al., 2012), and they have a large proportion of customers in the market (Barrera et al., 2010). The Android platform provides third-party developers with a wide ranging, free environment, resulting in the availability of many Android application programs, with a growing number under development. The Android system is conducive to the development of new application programs (Miyoshi et al., 2016). The application of Android mobile phones in grain counting programs will greatly increase the convenience and reduce the cost of grain counting.

Grain counting is an essential step for thousand grain weight measurement, and image processing method is an effective way to count grain. However, current grain counting algorithms based on image processing technology need long running time. Therefore, a fast counting algorithm is significance. Taking into consideration deficiencies and inconvenience of current grain counting based on image analysis technologies, this study attempts to design an efficient, convenient, and easy-to-use grain counting tool based on Android mobile phones. We expect the Android application program to require less computing, incorporate highly accurate counting formulas, and be easy and convenient to operate.

2. Materials and methods

2.1. Grain varieties

Three varieties of wheat and rice were respectively selected based on their morphological characteristics (include grain length, width, perimeter, size). The three wheat cultivars are Yangmai 23, Xumai 33, and Jimai 19. The two Indica rice cultivars are Liangyoupei 9 and Shanyou 63. The japonica rice cultivar is Yangjing 4038.

2.2. Software development tools

The software was developed using Eclipse and OpenCV for Android (http://opencv.org/platforms/android.html). The Java Native Interface (JNI) was used to enable Java to call the computer vision library. Our test results indicate that the program can be operated on a variety of Android mobile phones (AMPs). In the following sections, we demonstrate the process of software development and testing of a mobile phone. As an example, we used a KIW-TL00 mobile phone purchased from Huawei Technologies Co., Ltd. (China). This AMP incorporates a Qualcomm Snapdragon 616 1.5 GHz high-speed 4-core CPU. The phone has a 1300-megapixel video camera and an LED flashlight. The implementation flow of the grain counting application program is shown in Fig. 1.

2.3. Image capture

Images were vertically captured if possible. The grains were spread on a solid color board. The flashlight from mobile phone was used to unify the illumination condition. In accordance with photographing habits, the distance between the mobile phone and the grains was kept between 20 and 60 cm. A maximum contrast between the grains and the image background was created to ensure extraction of intact grains.

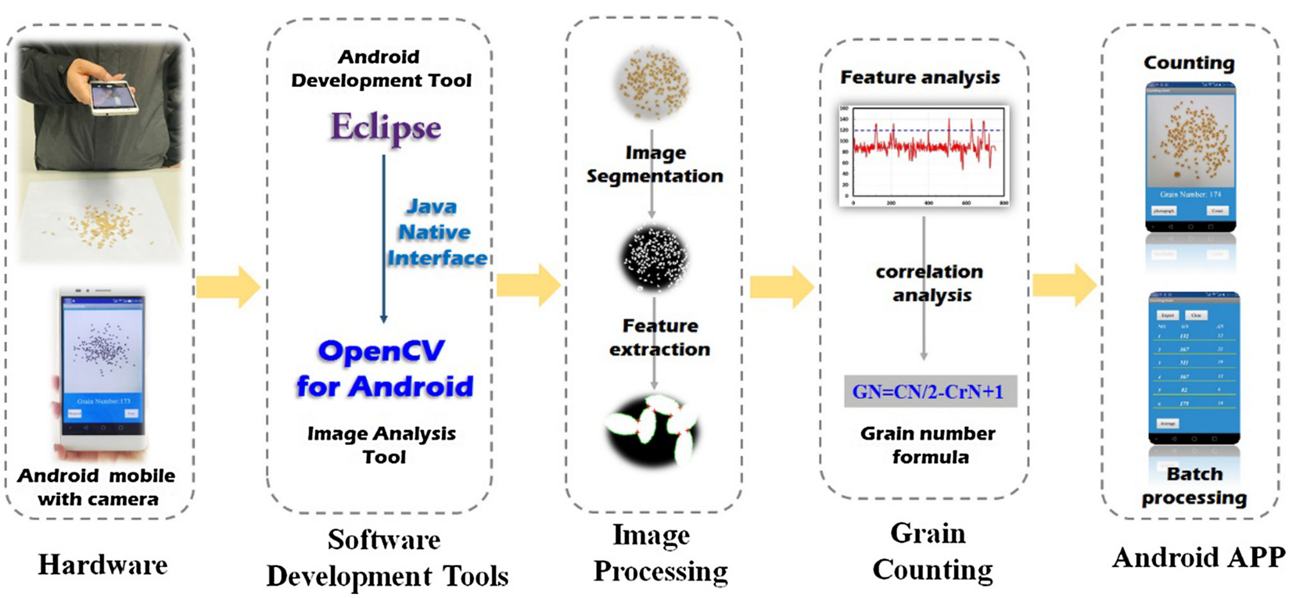

Fig. 1. System Implementation Flow. From left to right: images capture devices and methods, programming tools, image processing algorithm, formula of grain counting, software interface.