Journal of Stored Products Research 60 (2015) 67–74

Contents lists available at ScienceDirect

Journal of Stored Products Research

journal homepage: www.elsevier.com/locate/jspr

Discriminating and elimination of damaged soybean seeds based on image characteristics

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ARTICLE INFO

Article history:
Accepted 4 October 2014
Available online 25 October 2014

Keywords:
Damaged soybean seeds
Discriminating and elimination
Image characteristics
BP neural network

ABSTRACT

To identify and eliminate damaged soybean seeds, images of Kaiyu 857 soybean seeds including those with insect damage, mildew, and other defects were acquired with an intelligent camera. After splitting the kernels from the background through using the data fusion, morphological corrosion expansion and a series of image processing algorithms, we extracted eight shape features, three color features and three texture features as the input layer to set up a BP neural network classification model with an average recognition accuracy of 97.25%. The identifying and eliminating device was tested five times with a mixture of 1000 differently damaged soybeans of seeds. The average accuracy rates of identification and elimination for normal, mildewed, insect-damaged, skin-damaged, broken and partly defective kernels reached 99.24%, 98.2%, 96.4%, 85.6%, 92.4% and 85.2% respectively. The efficient processing speed of the device reached 125 grains per minute. The results are of significance for the development of precise selection systems for soybeans or other crop seeds.

1. Introduction

Soybean seeds are an important oilseed crop and a major source of protein (40% by weight) and oil (20% by weight) for consumption by humans and most domesticated animals (Begum et al., 2010). Thus soybean is commercially planted in many countries, including tropical rainforest and moderate monsoon regions. Environmental conditions and other post-harvest activities, such as mechanical threshing and artificial drying, in which the seeds were mechanically damaged, impact the final soybean seed quality and economic value (Esteve Agelet et al., 2012). In China, most soybean seed selectors designed and produced to clean the debris before storage are based on vibration, centrifugation or friction, as well as other mechanical principles. Nevertheless, the seeds must be precisely selected to eliminate the insect-damaged, fungal-infected and mechanically damaged seeds to improve the quality of standard seeds (Wang et al., 2010). The quality of soybeans (properly dried, no cracked or broken kernels, absence of foreign material) is important their storage and precision soybean seeding.

Visual inspection methods to precisely select soybean seeds are subjective, inconsistent and slow, and chemical methods are destructive and time consuming (Neethirajan et al., 2007; Singh et al., 2010), With the development of image processing technologies, cameras and DSP (digital signal processing) integration, machine vision technology and spectral analysis are widely applied, reliable, rapid and nondestructive methods to inspect quality and grade agricultural products. For example these methods are used to determine the internal quality of fruits, such as apples (Xing et al., 2005; Nicolaï et al., 2006), mangos (Valente et al., 2009), cherries (Zude et al., 2011), mangosteens (Terdwongworakul et al., 2012), apricots (Camps and Christen, 2009) and jujubes (Wang et al., 2010). Computer vision techniques have also been used to judge the maturity of grapes via the hyper spectral imaging of the grape skin or seeds (Ferrer-Gallego et al., 2011) and tomatoes by detecting the change in lycopene (Qin et al., 2011). In addition to fruits and vegetables, hyperspectral technology combined with computer vision techniques are currently widely studied to non-destructively detect corn and other grains. Using a visible near infrared hyperspectral imaging system and a classification procedure that incorporates both spectral and spatial features, approximately 94% of sprouted kernels and 98% of severely sprouted kernels were correctly classified using this technique to differentiate Canadian wheat classes (Mahesh et al., 2008). According to the surface distinction of crop grains, this method also can detect the internal quality, including insect-damaged wheat barley and maize kernels (Pedersen et al., 2003; Singh et al., 2009, 2010; Chelladurai et al., 2010; Del Fiore et al., 2010; Bauriegel et al., 2011; Mladenov et al.,

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http://dx.doi.org/10.1016/j.jspr.2014.10.001

2012). The potential of computer vision technology has been investigated to identify different grain types; varieties, classes, impurities, fungal-infections and insect-damaged (Pedersen et al., 2003; Mahesh et al., 2008; Chelladurai et al., 2010; Singh et al., 2010; Bauriegel et al., 2011; Mladenov et al., 2012). Neethirajan et al. (2007) noted that a major obstacle to the development of commercially useful machine vision systems for insect detection in grain is the limited rate of sample throughput. Simple, fast and reliable algorithms are needed to allow a statistically significant portion of a grain sample to be inspected in the short time available. Furthermore, the device complexity, particularly in terms of the camera type, computer specification and sample delivery system, must be minimized to make this approach cost effective. Another disadvantage is that such systems can only detect external insects in bulk grain samples (Neethirajan et al., 2007). Although many scholars have extensively investigated this aspect, mechanical devices combined with computer vision systems are rarely reported in the literature. The objective of this research was to develop an apparatus to discriminate and eliminate fungal-infected, insect-damaged and mechanically damaged soybean seeds. The specific objectives of this research were to:

- write a program in MATLAB to acquire the images of the damaged soybean seeds and pre-process the images.
- develop a classification analysis model by using a BP neural network.
- utilize model analysis results to selectively target soybean kernels by triggering an aspirator device to divert them, thus establishing a substantial hardware and software system of soybean seed identification and elimination.

2. Material and methods

2.1. Sample preparation

The typical soybean variety (KaiYu 857) was selected from a farm in ChangTu City, Liaoning Province. The experimental soybean kernel sample consisted of 100 artificially insect-damaged, fungal-infected (mildewed kernels) and mechanically damaged kernels, including broken kernels, kernels with damaged skin and partly defective kernels. The germination rates of mildew and insect-damaged soybean kernels are very low, and the germination rate of mechanically damaged soybean seeds is also lowered, thus, screening these seeds during seed selection is important. The mechanically damaged kernels were artificially prepared by applying pressure to kernels using a computer-controlled electronic tension and compression testing machine. Three types of mechanically damaged kernels were examined in this study: kernels broken into two parts (broken kernels), kernels with damaged skin and partly defective kernels and 100 samples of each were examined. Moreover, 500 intact soybean kernels were also randomly selected for testing. Thus a total of 1000 soybean kernels were tested.

2.2. Identifying and eliminating device

The identifying and eliminating device is shown in Fig. 1. The seeding apparatus needed to be suitable for precise metering, thus equally spaced seeding was a prerequisite to guarantee the experimental accuracy. The planter was made in-house from organic glass and plastic, and featured pits of different sizes on the seeding wheel to ensure its strong adaptability to kernels, high reliability, fast operation and suitability for precision seeding. The maximum precision of seed separation was 98%.

The color imaging system consisted of an intelligent camera (model no. VC2038/E made by Vision Components Corporation in Germany). Its processing speed was 150MHZ/1200MIPS as provided by a TI TMS320 C62XX processor. The camera integrated an RS232, 100 MB Ethernet interface, a multiple route digital I/O interface and SVGA video frequency output hardware interface. The image was displayed directly on screen via the high performance DSP processor and SVGA output interface. The camera used a standard camera link connector to connect a Matrox Meteor-IIPCI frame grabber board attached to a Pentium 4.3G computer. Two 50W LED lamps mounted at 45° and 40 cm away from the imaging area provided illumination to the camera.

The photoelectric sensor selected for this study was the LAS – T12NO8MD laser photoelectric sensor with reaction rate less than 3 ms, small laser emission angle and light beam focus. This camera is very sensitive and possesses strong anti-jamming capabilities.

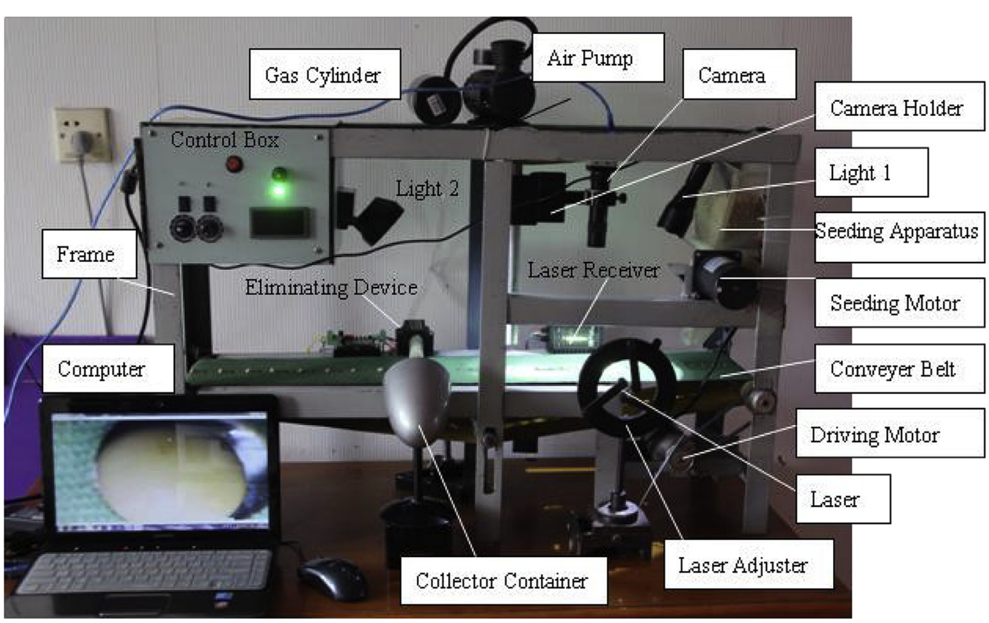

Fig. 1. Identification and elimination device for the damaged soybean seeds.