Identification of damaged corn seeds using an air-coupled ultrasonic technique

Abstract

Corn, an important staple ~~for~~ in many countries around the world, ~~could have~~ is subject to a very inefficient germination rate due to ~~worms damaging their~~ worm-damaged seeds. However, ~~the~~ air-coupled ~~ultrasonic technique~~ ultrasound is a rapid, safe and widely accepted method for the early detection of such damage. In this study, ~~I~~ we explored the current effectiveness and future prospects of this technique for ~~the identification of~~ identifying damaged seeds. ~~My process~~ Our procedure started with drawing a sample of 810 seed particles ~~seeds~~, ~~which consisted~~ consisting of 400 that were intact, 400 manually damaged ~~by hands~~ and 10 damaged by worms. Then ~~I~~ we used the principal component analysis (PCA) method to reduce the dimensions of air-coupling ultrasonic information and extract the top ten principal components. Finally, ~~I~~ we ~~built~~ constructed ~~the~~ a KNN decision tree by using SIMCA software and a Fisher recognition model by using MATLAB software. The pattern recognition was established by using KNN, ~~KNN~~ which has the most accurate recognition rate. ~~and~~ The correct recognition rate of modeling for the front and back data of the intact particles ~~is~~ was 98% and 100%, respectively; and for the manually damaged particles, ~~that damaged by hands from front and back the recognition rate is~~ 99% and 97%, respectively. The results show that the model developed by using air-coupled ultrasonic data can classify ~~the~~ corn seed particles both with and without holes ~~or not and that~~ to provide a basis for the development of a ~~corn~~ seed selection system, which has a significant role ~~for~~ in improving the ~~seed~~ clarity and the germination rate.

Keywords: damaged corn ~~seeds~~ seed identification, air-coupled ultrasonic principal component analysis, KNN

1 Introduction

Corn is one of the most widely cultivated food crops in the biosphere. Worldwide, the land area ~~of~~ devoted to planting corn ~~planted in the world~~ is the third ~~biggest~~ largest, after rice and wheat. The planting range is from latitudes of 58° ~~degrees~~ north to 40° ~~degrees~~ south. It ~~would be~~ is preferable to cultivate the first generation (self-cross line) of hybrid corn seeds because their parents have diverse and distinguishable genetic traits. The second generation of seeds is not as favorable because of ~~the~~ truncated features, which ~~yields~~ result in a smaller yield ~~less production~~. ~~So~~ Thus, the first generation ~~hybrid corn seed~~ is optimal, especially when inbred. Since healthy seeds will yield healthy ~~production~~ produce, ~~so~~ they must first be evaluated as healthy before they are sown. Clarity is one of the four ~~main~~ principal health indicators (along with purity, ~~clarity~~ moisture content and germination rate) used to determine ~~the~~ *sowing quality and authenticity ~~of corn seed and the~~ as well as impact ~~it will have~~ on *the commercial value ~~and germination rate~~ of the seeds. Seed clarity refers to a proportion ~~of seeds~~, i.e., the ~~percentage~~ ratio of normal ~~corn weight~~ to ~~the~~ total weight, including ~~the~~ impurities. According to the crop seed inspection procedures prescribed *in "GB3543-1983," the clarity analysis sample test is divided into four parts: ~~such as~~ (1) good seed, (2) waste seed, ~~and impurity~~ (3) impure ~~with life~~ organic, and (4) impure inorganic ~~or not~~. During the growing and storage process, some seeds are spoiled by worms, ~~which results~~ resulting in ~~the~~ a decrease ~~of~~ in ~~seed~~ the clarity of the ~~whole~~ entire batch. Worms ~~mostly~~ most frequently cause irreversible damage to the embryo of seeds, ~~making it so the seeds cannot germinate~~ rendering them incapable of germination, ~~which means~~ thus resulting in ~~that they are classified~~ their classification as wasted seeds. If these seeds are ~~then~~ subsequently mixed with healthy seeds, the quality of the ~~whole~~ entire batch ~~quality~~ will be adversely affected and ~~results~~ result in a lower germination rate. * _English Editor's Notes_: *(1) What [i.e., which noun] does the pronoun "it" refer to? (2) "Germination rate" appears to be one of the other three health indicators; hence, this term should not be used to define/identify/explain another one of the indicators. (3) I'm guessing that "GB3543-1983" is a Chinese government rule or regulation. As such, this term needs more detailed identification for the benefit of international readers.*

~~An air-sieve cleaner and spiral separator are~~ The main clarity processing methods use an air-sieve cleaner and spiral separator. The air-sieve screen cleaner is composed of an air-blast system and a series of screen meshes that use the buoyancy and width or thickness of seeds for cleaning. However, this method ~~will be~~ is affected by the size and shape of the impurities, the wind ~~speed,~~ velocity and mesh size during the clarity screening process, ~~these~~ factors ~~would lead to seed clarity~~ that do not meet the national standard,[1,2] let alone filter out damaged seeds. Therefore, ~~we need~~ a swift and secure screening method which can fulfill the demand of corn seed clarity processing is needed. ~~A number of~~ Several scholars who ~~detect~~ inspect agricultural products ~~found~~ have noted that impacted acoustic emission ~~was used as~~ is the basis for a device that separates pistachio nuts with closed shells from those with split-shells [3]. Also, Onaran et al. [4] developed a prototype system ~~that was set up~~ to detect empty hazelnuts by dropping ~~them~~ kernels onto a steel plate and processing the acoustic signal generated ~~when kernels~~ upon impact with the plate. They ~~realized~~ found that 98% of filled, developed kernels and 97% of empty kernels were accurately classified. In addition, Smail Khalifahamzehghasem and colleagues [5] developed an intelligent walnut recognition system by combining acoustic emissions analysis, a decision tree and a fuzzy inference system (FIS) ~~Smail's~~ that exhibited an overall classification accuracy ~~was~~ of 94.7%, thereby indicating that the model ~~could~~ can be implemented for separating ~~the~~ empty ~~walnuts~~ shells from filled walnuts. Another example is that of Mei ~~Y M~~ and Guo, [6] who ~~adopts~~ adopted a method based on the combination of a decision tree and fuzzy inference system to identify and classify ~~the~~ intact ~~corn particles~~, moth-eaten ~~particles~~ and mildewed corn particles by using a collision acoustic signal. The ~~experiment's~~ accuracy of their experiment was 97.6%, 92.9% and 96.4%, respectively, for each kind of particle. ~~and~~ Thus, those findings substantiated the effectiveness of ~~the~~ acoustic detection of ~~acoustic on the~~ corn seed damaged by worms. Although this technique provides a new effective approach for seed grading, ~~but this technique could~~ it should not be used for seed testing and sorting because of accuracy issues.

Air-coupled ~~ultrasonic~~ ultrasound is a rapid and nondestructive testing technology ~~It acquires~~ that has acquired high frequency, good direction, strong penetrating power and high precision features~~, such as ultrasonic~~. This technology ~~uses~~ using air as a coupled ~~medium~~ non-contact medium without the coupling agent~~, and~~ also possesses ~~a~~ good surface compliance and can identify very thin material~~, etc~~. ~~We have~~ Having consulted ~~modern~~ recent literature, [7,8] ~~have~~ gone through germination tests, and ascertained that the seeds used in the tests ~~are~~ were indeed ~~irradiation~~ irradiated by ~~the~~

~~ultrasonic~~ ultrasound and that the frequency and intensity ~~are~~ were ~~same~~ identical with the reported identification experiments, we are ~~sure~~ confident that ~~the~~ ultrasonic irradiation ~~has no~~ was not harmful to the corn seed. ~~So~~ Therefore, ~~the air-coupled ultrasonic~~ this method is very appropriate for identifying damaged corn seed particles. Air-coupled ultrasonic testing technology has been extensively used in numerous areas. A number of academics have applied it to the detection of both defective aviation components [9,10] and steel materials [11] ~~detection~~ and the analysis of material properties. ~~the~~ These studies have authenticated the assertion that the precision of defect detection can reach 1 mm [12,13].

In this study, the experiments used the pattern recognition method for detecting and distinguishing damaged maize seeds from ~~the~~ intact particles. Pattern recognition has been proved to have been used successfully in material defects testing. Li ~~Z~~ [14] choose the SVM (support vector base) as a pattern recognition classifier to identify ~~the~~ a flat bottom hole and a flat pan, two types of simulated defects, with ~~the~~ recognition rates of ~~is~~ 90% and 95%, respectively. Both ~~R.~~ Drai and colleagues [15] and Vieira~~A P~~ et al.[16] studied welding defects such as lack of penetration, incomplete fusion cracks and pore identification ~~and~~ as well as classification based on ~~ultrasonic~~ ultrasound, with accuracy rates above 85%.

These experimental outcomes assist ~~to~~ in the development of a recognition model based on air-coupled ~~ultrasonic~~ ultrasound for detecting and distinguishing ~~the~~ corn seeds damaged by worms from ~~the~~ intact particles. The goal is to compare and analyze a variety of pattern recognition methods to develop a high recognition rate and decent stability recognition model for ~~corn~~ seeds damaged by worms.

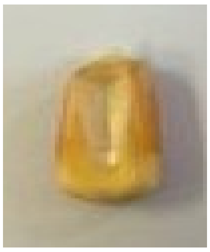
2 Materials and methods

2.1 Samples

~~There are~~ Numerous corn seed varieties exist, ~~and~~ each of ~~them~~ which varies in size, shape and humidity ratio. ~~but~~ However, the elastic modulus ~~would~~ will have minor transformations, and the level of ultrasonic wave diffraction around the seeds will be assorted. ~~Usually the~~ Stored seeds usually need to be processed due to their moisture content ~~of the seeds is~~ being less than 13%. Compared with the difference in ultrasonic signals ~~difference~~ that is caused by seeds with and without holes, the elastic modulus difference is caused by factors ~~that include~~ including ~~seed~~ moisture content ~~that~~ differing in range, ~~of moisture~~ i.e., less than 13%, ~~the different varieties~~ as well as variety, and ~~the different~~ degree of diffraction due to size, all of which have insignificant effect on ultrasonic signals. ~~In addition~~ Moreover, the species are usually detected ~~one by one~~ individually, rather than as multiple varieties mixed together. If different varieties of seeds are used to build the model, it will have ~~a bad~~ an adverse effect on the recognition performance model, in which case ~~and then we can create~~ a specific model ~~for those cases~~ can be created.

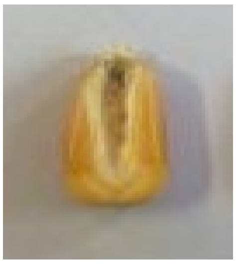
All of the 810 stored corn seed particles ~~of corn seeds that~~ from the three varieties used in this study were harvested in the Tong Zhou district of Beijing ~~Tong Zhou~~ in September. In this study, ~~lot of~~ many seeds with holes should have been used. However, because the amount of available seeds with holes drilled by worms ~~is~~ was less ~~in quantity~~, ~~so~~ this experiment focused on ~~the seed~~ manually damaged, instead of moth-eaten, particles ~~damaged by hands, instead of the moth eaten particles~~. The total ~~seeds are made up~~ consisted of 400 intact ~~particles~~, 10 worm-damaged ~~particles~~ and 400 manually damaged particles ~~damaged by hands~~. The shape of the seeds used ~~were~~ was flat in nature, ~~and~~ the ~~seed~~ dimensions ~~have~~ having a length of 12~~mm-~~to-14mm, a width of 7.5~~mm~~-to-9.5mm and a thickness of 3.8~~mm~~-to-5mm.

The hole size of corn seeds damaged by worms was different, ~~following this~~ as well as that in ~~the~~ those manually damaged, ~~holes damaged by hands also varied in size so the holes damaged by hands were also in dissimilar sizes to prove~~ thus demonstrating that the damaged seeds could be identified ~~whatever~~ regardless of the hole size. The ~~holes~~ hole sizes of the ~~corn~~ seed, ~~that damaged by bug or hand~~ regardless of how the damage occurred, ~~has~~ had a length of 8-~~mm~~to-9.5mm, a width of 2.5-~~mm~~to-3.5mm and a thickness of 1.5-~~mm~~to-2.5mm. ~~Seed particles~~ Physical diagrams of seed particles are shown in Figure 1.



(1)Intact particle (a) Front (b) Back

(2)Worm-damaged particle (a) Front (b) Back



(3)~~Hands~~ Manually damaged particle (a) Front (b) Back

Figure 1 Corn ~~seeds~~ seed particles ~~physical diagram~~

2.2 Data acquisition

The front sides of intact corn seeds are slightly concave; but ~~the~~ when ~~they have~~ there are holes, the front is much more sagged. Therefore, the reflections of the ultrasonic signal from ~~the front and back~~ both sides of the seeds are not identical, ~~so~~ resulting in inconsistency in the collected signal strength of the transmission wave ~~is not consistent~~, which may affect the recognition of seeds. Considering that in practical application the range of seeds is ~~not~~ uncontrollable, ~~so~~ we observed every seed ~~has been observed from~~ on both sides, i.e., front and back, to verify that the orientation of the seed ~~will~~ would not influence the recognition.

The air-coupled ultrasonic signal acquisition system used in this study is ~~shown~~ illustrated in Figure 2. The Ultran NCG500-D13 model ~~of the~~ transducer ~~Ultran NCG500-D13,~~ has a center frequency of 400 kHz and a 40mm center distance, taking the way of once-receive and once-~~send~~ sent. The first step in the signal acquisition process is to place one seed particle ~~seed~~ in the focal point of the ~~transceiver~~ transducer ~~focal point (~~To fulfill the ~~seed-placing~~ placement requirements, a plastic tape layer is ~~placed~~ inserted between the transducers~~)~~. [←Delete both parentheses] ~~Then~~ Second, ~~using~~ use any signal generator (e.g., Tektronix AFG3102) to produce a 12-cycle, continuous sine-wave original excitation signal with a frequency of 400 kHz. ~~Then~~ Third, ~~using~~ use a power amplifier (China: ekNet Electronics Company Amplifier Research 75A250A) ~~amplified~~ to boost the excitation signal (V_{pp}) to 200V ~~(China: ekNet Electronics Company Amplifier Research 75A250A)~~ to drive the ~~air-coupling ultrasonic~~ transducer and ~~transmission~~ transmitter from the seed. ~~Next~~ Fourth, ~~filtering~~ filter the ultrasonic signal received by the ~~air-coupled ultrasonic pulse~~ transmitter / receiver ~~that~~ with the controlling computer ~~named~~ (Panametrics-NDT Model 5900PR produced by ~~the~~ Pan American NDT) ~~company controlling~~, and ~~increasing~~ increase the gain to 60dB.The A/D conversion of the ultrasonic signal is completed by the NI-5114 card. ~~So~~ Thus, the professional analysis software ~~called~~ CScan1 ~~of~~ on the upper computer ~~could~~ can be convenient ~~to acquire~~ for acquiring the ~~data of~~ ultrasonic signal data. ~~The air-coupled ultrasonic signal acquisition system used in this study is shown in Figure 2.~~ The commercial mathematics software Matlab2014a ~~produced by~~ (MathWorks, Inc., USA) was used to simulate the model processes, including ~~process that is~~ de-noising, feature extraction, classification and identification.

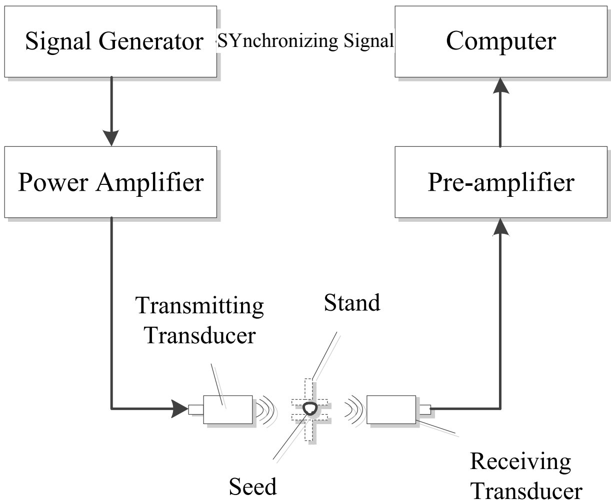
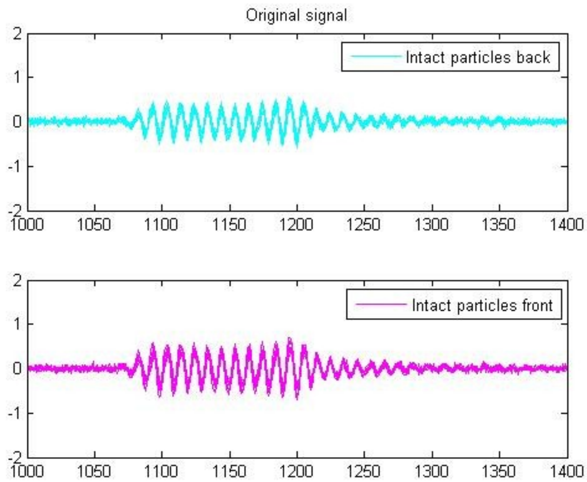


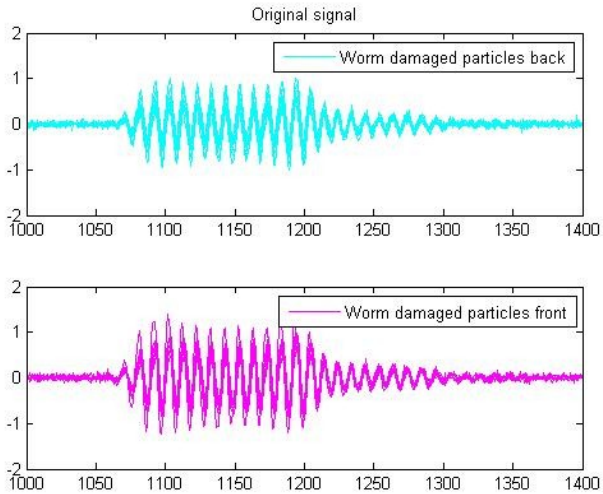
Figure 2 Air-coupled ultrasonic signal acquisition system

Our method included using ~~the air-coupled ultrasonic signal~~ this acquisition system to collect ultrasonic data ~~of~~ from both sides of 810 seed particles ~~from both ends~~ (front and ~~rear~~ back), ~~one by one~~ individually, ~~which gave us~~ yielding 1,620 sets of data ~~which had~~ having 2,048 individual data points to be collected. However, because there was some noise in the collected data, ~~so~~ it could not be utilized to develop a model. Therefore, we considered the data points from 1,000 to 1,400

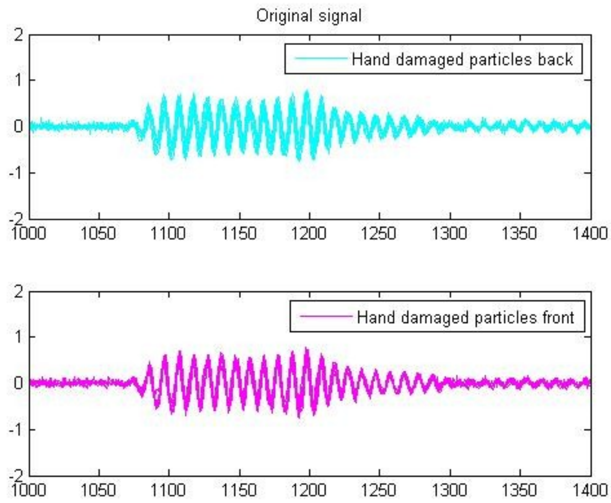
(~~shown~~ listed in Table 1) to shape a model and test ~~the model's~~ its performance. Graphs of ~~seeds~~ the original ultrasonic signals are ~~show~~ depicted in Figure 3(a) (b) (c).



(a) Intact particles



(b) Worm-damaged particles



(c) ~~Hand~~ Manually damaged particles

Figure 3 ~~Seeds~~ Original ultrasonic signals of seeds

Table 1 Acquisition of ~~corn seed particles~~ air-coupled ultrasonic signal numbers of corn-seed particles

Orientation	Intact particles ~~ultrasonic signal number (piece)~~	~~Hand~~ Manually damaged particles ~~ultrasonic signal number (piece)~~	Worm-damaged particles ~~ultrasonic signal number (piece)~~
front	400	400	10
back	400	400	10

2.3 Modeling

2.3.1 Noise filtering

The noise from the original air-coupled ultrasonic wave signal will have an impact on the recognition results. Since a single wave can be used to analyze a signal ~~simultaneously~~ in the time and frequency domains simultaneously, ~~it~~ the wave can effectively distinguish the mutation portion of the noise in the signal, thereby de-noising ~~the signal~~ it. In this study, ~~the~~ an orthogonal structure and compactly supported Daubechies wavelet ~~have been~~ were used to reduce the signal noise. We used ~~the~~ a Db4 wavelet to ~~decomposition~~ decompose the signal into five layers to obtain a set of wavelet coefficients; then, we ~~thresholding~~ thresholded the coefficient to ~~get~~ obtain the estimated coefficients to make the difference between estimated ~~coefficients~~ and wavelet coefficients as small as possible and ~~then~~ finally use the estimated coefficients to reconstruct the signal. After de-noising, the signal to noise ratio (SNR, SNR=20lg [*PS/PN*], with *Ps* and *Pn* ~~represents~~ representing the effective power of the signal and noise) was ~~raised~~ increased from 7.15 to 23.06. The de-noised data were then used as ~~the~~ input ~~of~~ for the feature selection.

2.3.2 Feature selection

The principal component analysis (PCA) [17,1718] method was adopted to reduce the dimensions of the air-coupled ultrasonic information. In this study, the ultrasonic signal data acquired ~~had~~ consisted of 2048 d, ~~making the signal data huge~~ an excessive and ~~overlapped~~ overlapping quantity. This redundant information ~~has~~ had insignificant ~~good contribution~~ value in the experiment. As ~~show~~ graphically plotted in Figure 4, after the feature was sorted, more than 97% of the primary data were ~~kept~~ retained in the top ten principal components; ~~so~~ hence, ~~the~~ those top ten ~~principal components~~ were extracted in this experiment. This extraction can make the data of high-~~dimension~~to-low-dimension space conducive for ~~the~~ analysis and for ~~the reduction of~~ reducing the loss of information.

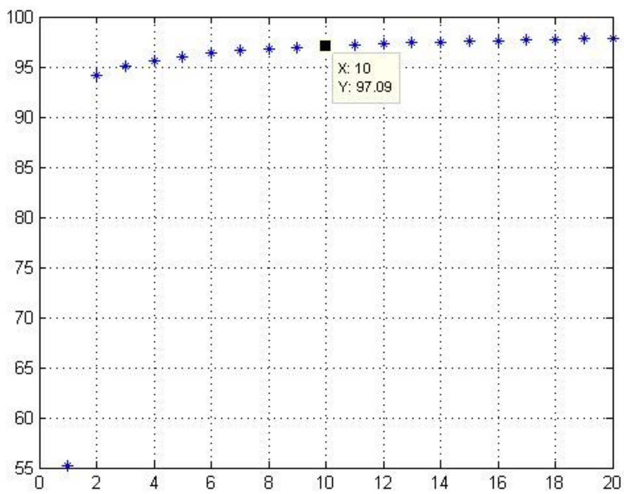


Figure 4 Accumulated contribution rates of prior 20-dimensional principal components

~~accumulated contribution rate~~

2.3.3 Classification methods

In this experiment, four statistical pattern recognition methods, namely, the Nonlinear K-neighbor（KNN）, SIMCA, linear Fisher Distinguish and Decision Tree cluster,[19] ~~have been~~ were applied to build recognition models for corn seeds ~~that have~~ having holes and worm damage The collected data ~~that have~~ possessing extracted features were used to build four recognition models by the ~~four~~ aforementioned methods, respectively, in KNN, k=4. The model prediction performance was evaluated by a correct recognition rate, ~~Correct recognition rate is~~ defined as the number of samples in the correct identification /the number of the sample which should be identified×100%. [Editor's Note: Should this rate be expressed as a mathematical formula?]

3 Results and discussion

3.1 Comparison of manually and hand-damaged particles ~~compared with worm damaged particles~~

In ~~the consideration of~~ considering the difference between ~~the hand damaged~~ manually and ~~the~~ worm-damaged seed particles, ~~there was a hypothesis~~ it was hypothesized that this model was ~~not~~ incapable of identifying ~~the seed~~ particles ~~which are~~ drilled by moths because ~~this~~ the model is based on ~~the hands~~ identification of manually drilled particles. [Editor's Note: Do you consider worms and moths to be the same kind of damaging agent?]

Front and back ultrasonic signal data ~~was~~ were collected from one hundred particles with hand-drilled holes and ten moth-eaten particles, ~~then de-noised~~ after which the signals data were de-noised and ~~lastly extract~~ the first ten-dimensional features finally extracted by using PCA. ~~It is~~ Obviously, ~~to see~~ one may observe that the front and back data of both hand-drilled ~~holes particles~~ and moth-eaten particles are mixed together in the PCA features space (Figure 5).

~~It shows~~ Thus, it has been demonstrated that the difference between moth-eaten

~~particles~~ and hand-drilled ~~holes~~ particles of the same variety are ~~not~~ indistinguishable, ~~which has~~ exhibiting almost no effects on the results. Therefore, the ~~particles~~ manually drilled ~~by hands~~ particles could be replaced with ~~the particles~~ moth-drilled ~~by moth,~~ ~~This is~~ which became the basis for follow-up in this study.

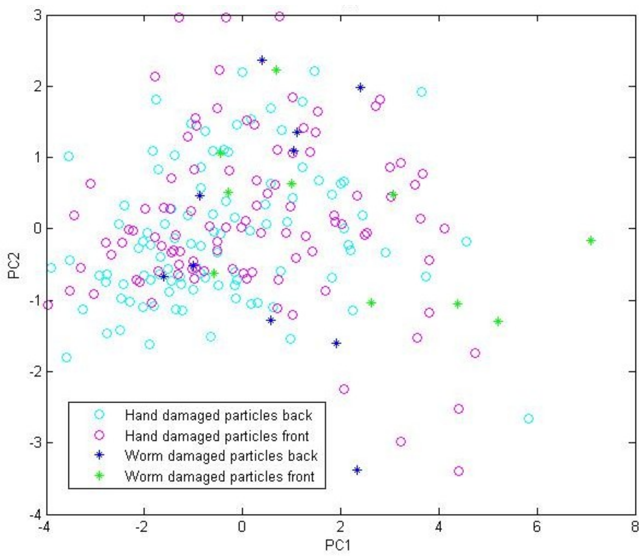


Figure 5 Spatial distribution of ~~the~~ manually ~~particles with hand damaged~~ and moth-damaged particles in PCA [Editor's Note: Revise all text on the image according to the following patterns: Manually damaged particles, back and Worm-damaged particles, back, noticing the punctuation.]

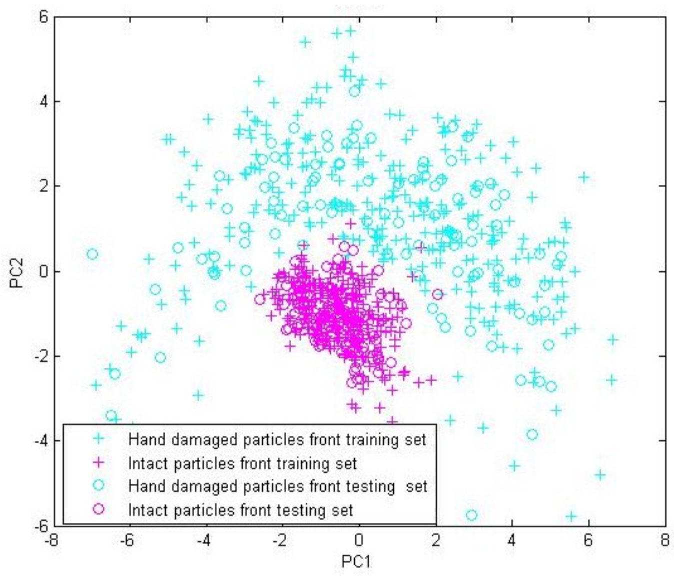
3.2 Comparative analysis of ~~the~~ recognition models

3.2.1 ~~Both sides~~ Each side of ~~the~~ data model

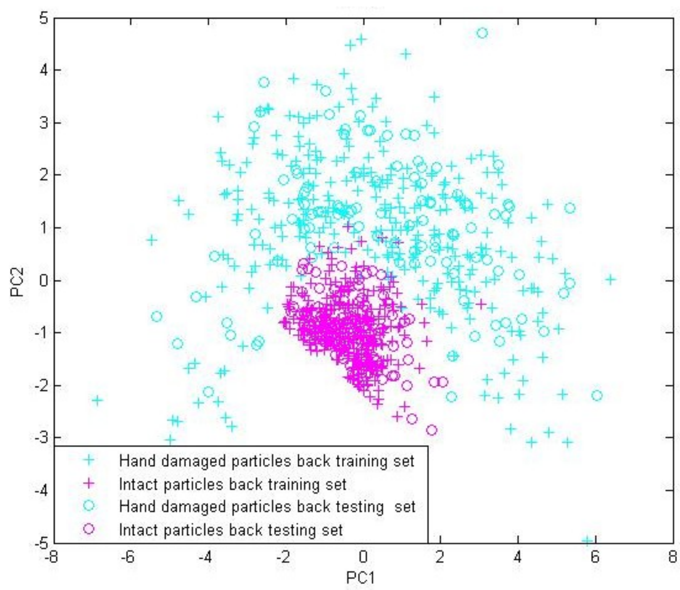
~~Recognition model~~ The structure of the recognition model ~~is as follows,~~ consisted of choosing intact and ~~the~~ manually damaged ~~holes~~ seeds to obtain front-side air-coupled ultrasonic signal data from 300 pieces, respectively, ~~leaving~~ yielding a total of 600 pieces of data ~~as~~ for a training set. The data was used to set up four kinds of recognition models ~~respectively~~. ~~The intact and manual holes seeds have~~ We obtained positive air-coupled ultrasonic signal data from100 pieces of intact and manually damaged seeds, respectively, producing a total of 200 pieces of data as an ~~testing~~ experimental set to test the correct identification rate of the model. Then, the ~~testing~~ experimental set ~~data will go through~~ underwent the same de-noising and feature extraction processing regarding ~~the~~ front-side ultrasonic data of intact and damaged particles, and vice versa.

The PCA spatial distribution of data from ~~both sides~~ each side of the particles with hand-drilled holes and the intact particles, is ~~shown~~ graphed in Figure 6 (a), (b). In addition, the minority particles ~~have~~ exhibited a clear boundary between ultrasonic data, ~~either~~ whether from the front or the back of the vast majority of both intact ~~seeds~~ and damaged seeds. Therefore, the ultrasonic method can distinguish between intact ~~seeds~~ and ~~the~~ hole-damaged seeds ~~with holes~~. The difference between ~~the~~ different particles of the same variety is greater than the difference between the front and back signals ~~of~~ from the seeds. These results thus suggest that ~~the~~ intact particles can be separated from ~~the~~ damaged ~~particles~~ ones.

The intact ~~particles~~ and ~~holed~~ damaged particles were ~~developed~~ classified by the four identification methods ~~which are shown~~ listed in Table 2. From the table, it can be concluded that the KNN, SIMCA and Fisher identification models have better prediction results, especially for the data ~~of~~ pertaining to the back side of intact particles ~~on the rear side~~. The correct recognition rate is 100% ~~in~~ for all sets. Compared with the other three methods, the KNN ~~acquired~~ obtained the best recognition ~~effects~~ rates. The correct recognition rates for ~~the either~~ each side of both the intact ~~particles~~ and ~~holes~~ the damaged particles are greater than 97%, ~~making~~ rendering the model more reliable. The ~~truthful~~ correct ~~recognition~~ rate of the model based on the decision tree is less than that of the others, being 87% for the front side of ~~holed~~ the damaged particles ~~(front) is 87%~~. However, it ~~still~~ remains ~~has~~ to be proved that ~~the~~ air-coupled ultrasonic technology is feasible to use for the identification of ~~the~~ corn seed particles, whether ~~is~~ intact or ~~holes~~ damaged.



（a）Front side



（b）Back side

Figure 6 PCA spatial distribution of data from ~~both sides~~ each side of ~~the~~ particles with ~~hand drilled holes~~ manually damaged and intact particles [Editor's Note: Revise the text on the above images according to the following patterns: Manually damaged particles, training set, back; Manually damaged particles, experimental set, back. Revise likewise for Figure 7.]

[Editor's Note: Revise "Holes" to "Damaged" 4 times in the text of Tables 2 & 3 below.]

Table 2 Identification results ~~of~~ from different models for ~~the two sides of~~ data of each side unit：%

	Identification method	KNN		SIMCA		Fisher		Decision tree	
		Intact	~~Holes~~	Intact	~~Holes~~	Intact	~~Holes~~	Intact	~~Holes~~ Damaged
correct recognition rate	Front	98	99	99	90	99	90	94	87
	Back	100	97	100	96	100	96	93	92
	Average	99	98	99.5	93	99.5	93	93.5	89.5

3.2.2 Modeling by ~~the~~ two-sided seed data

In the actual production application of corn-seed clarity processing, the model is used to identify the damaged seeds from a large amount of seeds where the orientation is uncontrollable; ~~so~~ hence, ~~we need to~~ building a model that can identify seeds, ~~whether~~ regardless of the orientation, is ~~front or rear~~ needed. The evolution of the identification model process is as follows.

1. Select a sample of 300 seed particles consisting of 150 intact and 150 hand drilled; ~~having equal share of 150 each. Then~~

2. Follow the air-coupled ultrasonic signal data on both sides of the elements of the ~~above~~ selected sample, ~~so there is~~ to obtain a total of 600 pieces of data ~~that are~~ to be used for ~~the model, in order to~~ establishing four kinds of recognition models; ~~Now,~~

3. Choose another sample ~~comprising~~ consisting of 100 particles drawn equally from intact and hand-drilled; ~~particles equally then~~

4. Replicate the ~~above~~ aforementioned trial; ~~then~~

5. Total ~~200 particles~~ the data on 200 particles to ~~experiment~~ test the performance of the model; ~~performance. Finally,~~

6. Collect the statistical data from the correct recognition rate model of intact ~~particles~~ and ~~holes~~ holed particles, respectively.

The PCA spatial distribution of the ~~particles~~ front and back side data ~~with~~ for both ~~hand-drilled holes~~ damaged and intact particles is shown in Figure 7. As ~~shown~~ listed in Table 3, KNN ~~could~~ can be considered as the preeminent pattern recognition method, ~~and~~ the model of which ~~have~~ has higher factual recognition rate for the ultrasonic data from the intact and ~~holes~~ damaged particles.

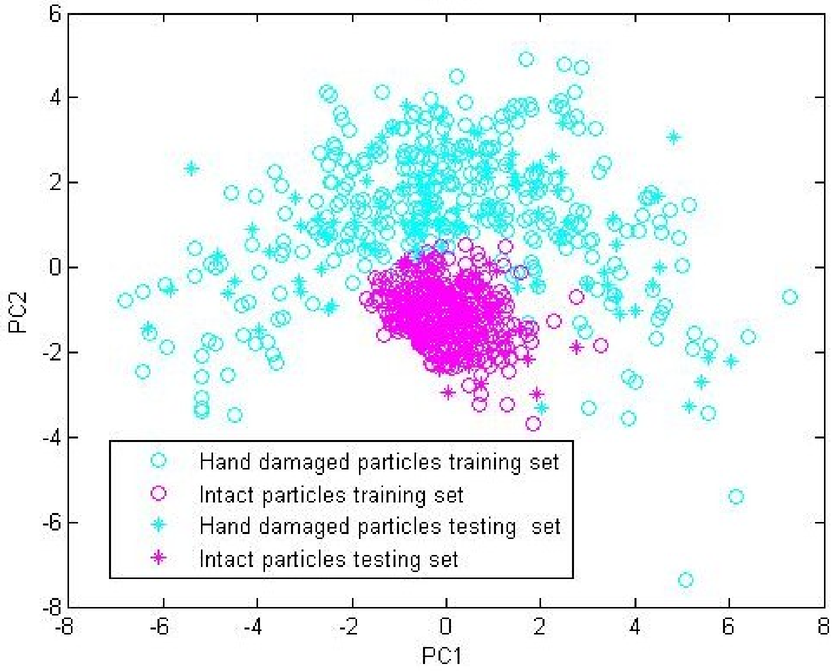


Figure7 Spatial distribution of ~~the hands~~ manually damaged ~~particles~~ and intact particles in PCA

Table 3 Recognition results ~~of~~ for different models

unit： %

Identification method	**KNN**		**SIMCA**		**Fisher**		**Decision tree**	
	Intact	~~Holes~~	Intact	~~Holes~~	Intact	~~Holes~~	Intact	~~Holes~~ Damaged
correct recognition rate	100	97	99	94	99	94	100	94

3.2.3 Comparative analysis of ~~the~~ models

~~From~~ According to Tables 2 and ~~Table~~ 3, the data ~~of~~ for the seeds taken from either side is either separate or hybrid. The correct recognition rate of the KNN model for intact and ~~holes~~ damaged particles is the most precise among the four methods. This result is supported by the argument [20] that the KNN recognition method ~~while making judgments~~ uses the factual information of all the known points while making judgments; ~~and~~ therefore, the recognition effect will be better than with other methods.

As ~~shown~~ listed in Tables 2 and ~~Table~~ 3, most of the recognition methods are ~~decent~~ acceptable for the intact particles. The main reason may be that ~~the~~ those particles are similar in shape, size and in ~~embryo's~~ embryonic uniformity. Due to the size and the depth of the holes, the difference is relatively ~~big~~ large between ~~holes~~ the damaged particles. ~~So~~ Thus , the attenuation of the ultrasonic signals will be different after penetrating into the seed, ~~and~~ the difference ~~of~~ in the signals ~~make~~ causing the ~~seed samples~~ distribution of the seed samples at the PCA space to be relatively dispersed. The distance of a ~~little~~ small part of the damaged particles from the center is greater than the distance from the intact particles to the center of the model ~~center~~. Therefore, the ~~holes~~ damaged particles were incorrectly identified as intact seeds, ~~which will~~ thereby leading to ~~reduce~~ a reduction in the correct recognition rate.

Among researchers ~~doing~~ engaged in similar studies ~~scholars~~, Mei ~~Y M~~ and Guo ~~uses~~ used an impact sound signal to identify intact ~~particles~~ and insect-damaged particles of corn seeds ~~whose~~ at accuracy rates ~~is~~ of 97.6% and 92.9%, respectively. In ~~this~~ our study, the accuracy of the recognition rates ~~about~~ for intact ~~particles~~ and ~~insects~~ insect-damaged particles ~~is~~ was higher than the minimum recognition rates of 3.6% and 5.9%. However, if compared with the model established by the KNN recognition method in this ~~paper~~ research, the correct recognition rate ~~of~~ for both intact ~~particles~~ and ~~holes~~ damaged particles is still lower.

4 Conclusions

The results ~~showed~~ have demonstrated that the model established by using air-coupled ultrasonic data is the best for identifying ~~the~~ intact ~~particles~~ and ~~holes~~ damaged particles of corn seeds. The pattern recognition established by KNN has acquired the highest average accurate recognition rate and the highest correct recognition rate ~~of~~ among the tested models for intact ~~particles~~ and ~~holes~~ damaged particles, which may reach 97% and 100%, respectively. ~~While some model~~ Although the precise recognition rate is relatively low for some models, the lowest range is 87% to 93%. The results of this study have ~~a~~ great practical significance in ~~corn seeds~~ the production and processing ~~in practical life~~ of corn seeds. ~~It~~ Our method can individually pick out the moth-eaten seeds~~, one by one,~~ that are mixed ~~in~~ among a large number of intact seeds, ~~So, it can improve~~ thereby improving the clarity of the seed and furthering the ~~seed~~ germination rate. Finally, ~~it~~ this method satisfies the detection requirements ~~of the seeds detection~~ without damaging ~~their~~ the physical and chemical properties of the seeds, thus making it ~~is~~ an ~~efficiently~~ efficient and environmentally-friendly ~~detection~~ method. [CJR stopped editing at this point.]

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