International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: IV Month of publication: April 2023

DOI: https://doi.org/10.22214/ijraset.2023.51346

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue IV Apr 2023- Available at www.ijraset.com

The Most Effective Method to Recognize and Assess Bugs in Food Grains

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Abstract: Food grains that are stored are significantly damaged by insects. Additionally, the nutritional and marketability of stored food grains are impacted by insect pestilence. The application of corrective measures necessitates the prompt identification and surveillance of insects in the stored food grains. Insect traps, Berlese funnels, visual lures, pheromone devices, and other methods of visual inspection are a few of the most common approaches that are extensively utilized in commercial grain storage facilities or granaries. Of late, electronic nose, strong stage miniature extraction, warm imaging, acoustic recognition, and so on. have been shown to be effective at identifying insects. The most important aspects to take into account when choosing a method are its capacity for in-situ early detection, monitoring, cost, dependability, and labor requirements. An important concern for reducing losses in bulk storage warehouses is the detection of hidden infestations, whose population may be many times greater than that of free-living insects. This allows for prompt fumigation or grain disposal. This paper surveys a portion of the broadly involved location techniques for early recognition of bugs' pestilential exercises in put away food grains as well as a portion of the clever advances with an accentuation on acoustic strategy, which has a decent business potential.
Keywords: Location technique Post-collect misfortunes Pestilential Acoustic location Electronic nose

I. INTRODUCTION

Because the world's population is growing at a rapid rate and will reach over 9.1 billion by 2050, global food security is a pressing issue (FAO, 2014; Parfitt and others, 2010). According to the World Bank (2011), between 20% and 40% of post-harvest losses (PHL) occur during field and post-harvest operations, with 55% of these losses occurring during storage. According to Asrar, Ashraf, Hussain, Zia, & Rasool (2016), insect infestations worldwide cause damage to food grains that ranges from 10% to 40% annually. According to Jha, Vishwakarma, Ahmad, Rai, & Dixit (2015), cereal storage losses in India ranged from 0.75 to 1.21 percent, while losses in the case of oilseeds and pulses ranged from 1.18 to 1.67 percent and from 0.22 to 1.61 percent, respectively. The number of insects, their stages of development, and the extent of an infestation can be tracked over time through monitoring of stored food grains. It also shows the activity of the insect in relation to the conditions of the environment and determines the effectiveness of insect pest management measures. It is necessary to develop sophisticated insect infestation detection techniques with increased sensitivity in order to lessen these losses and guarantee the secure storage necessary for sustainable agriculture production. This review paper will examine conventional approaches and present a bird's-eye view of recently developed technologies for insect detection in stored products. The acoustic detection of insects in stored food grains has received a lot of attention.

II. DETECTION OF INSECT PRESENCE

In grain storage facilities, several conventional methods are utilized, the most common of which are visual inspection, probe sampling, and the insect trap method. These strategies are basic yet tedious, work concentrated and emotional. The following sections provide a brief overview of a few well-known strategies. In this study, the workpiece is made of HCHCr-D2 steel. Size is offered in square, flat, and round shapes. This substance is primarily applied in the manufacturing of moulds and dies, and time, pulse off time, and WEDM current affect the rate of material removal (MMR), as well as the surface roughness (SR). The item code for material HCHCr steel is D2. Table 1 displays the chemical composition of HCHCr-D2 Steel.

Visual inspection can be used to find insects in food grains that have been stored. It is a standard method for comparing quantitative methods because it is uniform, subjective, and qualitative (Semple, 1980). Without drawing grain samples or looking for residual infestation within the storage bags, it is possible to observe the presence of eggs, adult insects, and infested grains with the naked eye. Service of Agribusiness, Fisheries and Food Examiner, England, fostered a few documentations for the utilization of sack.

Character	Specificity	Number of bugs
C - Clear or none	No insects	Require assurance from cross-pervasion and normal investigation.
F - Few or light	sporadic occurrence of few insects	fewer than 20 insects per 90 kg of sieved sample for a few notations (needs to be de-infested soon). For light notation, 20–300 insects per 90 kg sieve sample.
MN - Moderate numbers	Absence of insects in sacks	50-300 insects per 90 kg sample that has been sieved
LN - Enormous numbers	regular occurrence and formation of a small population of insects	300-1500 bugs for every 80 kg sieved test.
VLN - Extremely enormous numbers	large numbers of insects crawling on the surface of the stack intense presence of insects, which can be heard and are represented by dead skins around the stalk.	> 1500 insects per 90 kg sample that was sieved

(Table 1).

A. *Probe Sampling and Trap Method*

Sieving and probe sampling are the two most prevalent techniques; some way it is strenuous and monotonous. Tests are utilized in this technique to separate grains (0.5-1 kg) from the put away canister. Sifters are used for screening the bugs from the grains. Grain capacity containers are used to store tests for long periods of time; a regulator genuinely disposes of it and ostensibly explores them, subsequently making it a drawn-out and a portion of the time problematic method These contraptions (see Fig. 2) are helpful for quickly identifying and monitoring insect infestations in stored food grains. The movement of insects toward the air is used as a design idea. The two-in-one probe trap is very effective because it combines a pitfall trap and a probe. It is best suited for capturing pulse beetles because they never stay on the grain surface. A cup with holes and a lid in the shape of a cone is an indicator device. It is held in place at the bottom by a container and a circular dish coated with a sticky substance. The 250 nm ultraviolet light traps embedded with a 4 W germicidal lamp are used in storage at 1.5 meters above the ground. Pheromones are compound substances that bugs emit and are used in bug control traps. These are used for bug-to-bug communication.Fig.1.HCHCR D2 steel

III. OLFACTORY BASED METHODS

A. *Solid Phase Micro-Extraction (SPME)*

Insect infestation and grain quality evaluation odor detection methods are gaining popularity. Also, this strategy works with early identification of pervasion, stockpiling age assurance, varietal segregation of food grains and so forth. SPME used headspace techniques to separate volatile compounds from vaporized samples. These compounds were then condensed, and gas chromatography-mass spectrometry (GCMS) was used to quantify the volatiles. The SPME method's efficiency and sensitivity are influenced by extraction temperature and time.

B. *Electronic Nose (E-nose)*

According to Wilson (2012), the intervention of various electronic nose (E-nose) sensor types and instruments is based on the concept of electronic aroma detection (EAD). There are three parts to the e-nose: a system for interpreting the data, a data pre-processor, and a set of smell sensors. The sensor set alters the electrical properties of stored food grains in response to the presence of volatile compounds in the headspace. It includes a predefined database for distinguishing particular volatiles.

In EDM, the tool electrode and workpiece electrode are both completely submerged in a dielectric fluid such as Kerosene oil, EDM grade oil, transformer oil, distilled water, etc. Typically, the tool is made negative by being connected to the cathode (which is called the negative polarity) and made positive by being connected to the anode (which is called the positive polarity). Intermittent electric discharge is used to machine unwanted material because dielectric strength breaks down at high enough voltages.

Electric discharge machining is done in this way because of the intermittent discharge between the gaps of 10.5 and 125.7 m, which happens after each pulse on duration, produces a very high temperature in a fraction of a second that melts the metal at such a high temperature in the range of 8000oC to 12000oc

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IV. ELECTROMAGNETIC-SPECTRUM BASED METHODS

A. *Imaging Methods*

Machine vision inside noticeable area. An emerging field that combines digital and image processing technology with mechanics, optical instrumentation, electromagnetic sensing, and electromagnetic sensing (Patel et al., 2012). It utilizes the rule of article acknowledgment and characterization based on data extricated from the picture caught by utilizing the camera (Sun, 2016). It is an efficient, consistent, cost-effective, and objective method of inspection that could be used in This non-destructive method helps accelerate the development of automated processes because of its speed and precision, which can meet the ever-increasing demands for production and quality. Image acquisition, image processing or analysis, and recognition and interpretation are the three main steps in machine vision technology. Picture obtaining comprises of catching a genuine picture by utilizing cameras, scanners, recordings and so forth. and converting it into an electronic image.

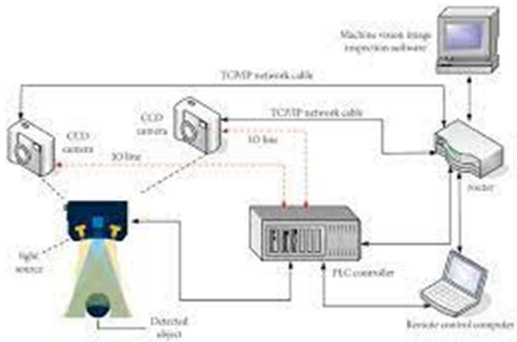

Fig.1

B. *X-beam Imaging.*

An encouraging method that makes use of a non-contact sensor to inspect large samples while significantly providing information is X-ray imaging (Yacob et al., 2005). Soft X-ray imaging is a quick, non-destructive, and direct method that is used to find invisible insects in stored food grains (Karunakaran, Jayas, & White, 2003), grade agricultural produce, and determine the internal quality of the produce (Kotwaliwale et al., 2014). The X-ray source that is included in the imaging system; X-beam converter; image capture system and isolated casing (Kotwaliwale, Kalne, & Singh, 2011). A casing separated the imaging medium from the radiation around it and captured the images (Kotwaliwale, Subbiah, Weckler, Brusewitz, & Kranzler, 2007). Electromagnetic rushes of 0.1-10 nm frequencies with 0.12-12 KeV energy are utilized as delicate X-beam for inner examination in exceptionally less time (3-5 s) to create a X-beam picture

Chelladurai, Karuppiah, Jayas, Fields, and White (2014) utilized the delicate X-beam and close infrared (NIR) hyperspectral imaging methods to obtain pictures of soybeans swarmed by C. maculatus alongside uninfested bits. 33 highlights were extricated by delicate X-beam imaging and 48 elements were separated by hyperspectral imaging for information examination. Various phases of invasion were arranged by utilizing LDA and quadratic discriminant investigation (QDA) models. For soft X-ray images, approximately 86% of uninfested and 83% of infested C. maculatus grains were classified by LDA. Principal component analysis (PCA) was used to classify hyperspectral data at wavelengths of 960 nm, 1030 nm, and 1440 nm. The accuracy of the classification of the egg and larval stages was improved by combining X-ray and hyperspectral features.

Thermal imaging. Thermal imaging is a nightvision

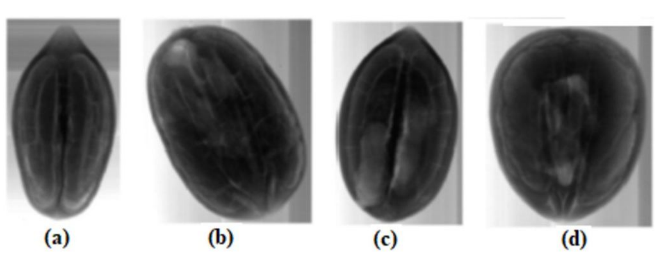

Fig. 2. X-ray images of pecans with a variety of visible characteristics. a) Excellent nut; b) bug harm to one cotyledon from inside; (c) An insect-visible hole; d) insect harm (with permission from Kotwaliwale et al. 2007a).

V. NON-IMAGING METHODS

Electronic insect counter with a grain probe (EGPIC). A mechanized detached grain test, known as Electronic Grain Test Bug Counter gains offsite checking and location of bug bothers and remotely shows the information of pervasion levels in put away food grains. A probe, system circuitry, a data logger, and a user interface make up this device. Electric power and circuitry are kept outside the storage structure to avoid the risk of grain dust explosions, and only low voltage, high impedance sensor leads are routed through the grains from the beam generation/detection circuitry to the sensor head. Sensor data is sent to a computer, which analyzes the signals and creates timestamped records of detection.

NIR spectroscopy. Near-infrared spectroscopy, or NIRS, is a method for determining the concentration of biological substances like water, protein, starch, and so on. by measuring the sample's dispersed reflectance, interactance, or transmittance between 780 and 2500 nm. According to Elizabeth, Dowell, Baker, & Throne (2002), it is a non-destructive, speedy, accurate, and cost-effective method that can be used for both internal and external detections in fruits, vegetables, cereals, and pulses. Kim, Phyu, Kim, and Lee, 2003; Xing and Guyer, 2008). Reflectance mode estimates the light reflected or scattered back from the outer layer of the article. When transmittance evaluation makes it difficult to access internal information, interaction mode is acclamatory (Kavdir, Lu, Ariana, & Ngouajio, 2007). Ridgway and Chambers (1996) announced the utilization of NIR reflectance spectroscopy in the recognition of interior pervasion by Sitophilus granarius (L.) in wheat. Chelladurai and others 2014) utilized delicate X-Beam imaging and NIR hyperspectral imaging in the recognition of C. maculatus and characterized the invaded and sound portions of soybean.

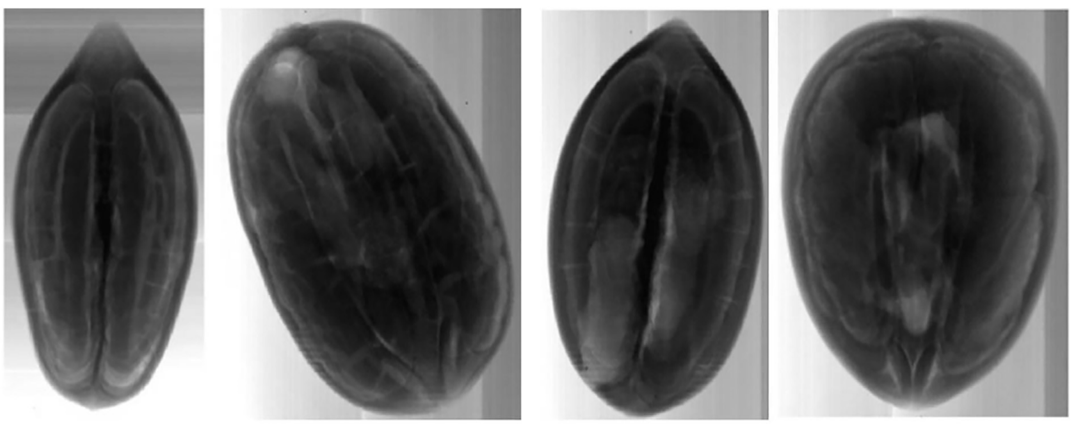

Fig. 3. Pseudocolor images of non-fungal samples at (a) 0 s, (b) 180 s, and (c) 210 s and fungal samples at (d) 0 s, (e) 180 s, and (f) 210 s are represented in grayscale.

A. Acoustic Detection

Acoustic technology is based on the idea that the type and density of insects within a stored grain mass can be estimated by monitoring the sound caused by insects moving and feeding. According to Eliopoulos, Potamitis, Kontodimas, and Givropoulou (2015), it has demonstrated promising results when it comes to the detection of both internal and external insects in the grain mass during the early stages of infestation by means of insect feeding sounds. Mechanical or acoustic waves are detected by acoustic sensors. Acoustic waves are influenced by the properties of the material or object they pass through as well as any obstacles in their path as they travel through it. Because of this, speed or adequacy of the acoustic waves hoses and afterward these progressions are converted into advanced or simple sign through transducers. It for the most part involves the piezoelectric substrate as a sensor. Recognition of covered bugs in grain bit relies upon enhancement and sifting of their development and taking care of sounds. Characterization of designated sounds from different sounds and other restricting elements, for example, sensor responsiveness, sound-commotion proportion, the scope of sensors and so on., restrict the use of acoustic devices. Increased receptivity and credibility have been made possible by technological advancements, including the use of software tools for digital signal processing and improved sensors. When separating the targeted noise from the background noise, pattern features—both spectral and temporal—are also helpful. Insect sounds were separated from background noise using standard speech recognition tools like hidden Markov models and Gaussian mixture models.

Removing grain samples from the storage bin, the insect sound was detected. Above 90% location level could be accomplished at the lower part of the construction. They recommended it as a simple and fast strategy for location and populace thickness assessment of bugs. Kiobia et al. (2015) fostered a sound and vibration controlled framework to distinguish Prostephanus shortens and S.

Zeamais in maize capacity for dealing with the bug in put away food grains in Sub-Saharan Africa. They discovered that the sensors could measure larval impulses within a 25 cm range. Programming apparatuses were additionally evolved based on contrasts in the phantom and worldly example of bug sounds related with contrasts in physiological exercises. According to Mankin & Moore (2010), feeding sounds had a wider, higher-frequency spectrum than low-energy moving sounds. Trains of sequential bug driving forces (200 ms or less) laid out more huge sign of bug presence than the single motivation (Njoroge et al., 2016, 2017).

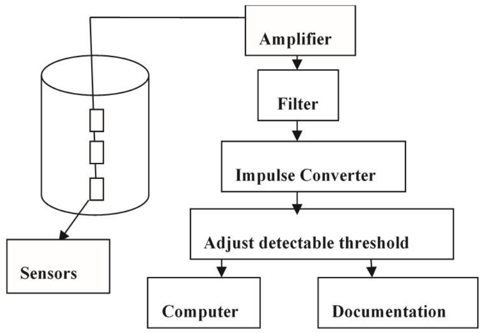

Fig. 3. A diagram of the acoustical probe and signal processing system used to find insects in grains (adopted from Fleurat-Lessard, 2006).

Acoustic insect detection probe that operates from the bulk grain's surface to detect and identify the sounds of various species and stages of primary insects in long-term storage. In a 30 kg grain mass, the apparatus can predict live concealed insects of all stages with a confidence factor greater than 90%. Eliopoulos and others 2015) demonstrated that the use of bioacoustics to locate adult wheat beetles within the grain mass was effective. The most significant beetle pests of stored cereals and pulses were used, and the population densities ranged from 1, 2, 10, 20, 50, 100, 200, and 500 beetles per kilogram of grain. The linear model did a great job of explaining the connection between population density and the number of sounds.

B. Signal Processing

Speech recognition techniques are used in the signal processing of recorded sound for the purpose of separating targeted noise from background noise. For the examination of acoustic signs, different sorts of windows are utilized for spectrogram investigation.

C. Filtration and Window Function

A mathematical function used to smoothly draw a sampled signal down to zero at the edges of the sampled region is called a window function (also known as an apodization or tapering function) in signal processing (Prabhu, 2013). The window function's spectrum can be given in both the frequency and time domains. More than one sample (at least two full cycles) is used in acoustic signal analysis.

D. Acoustic Range Highlights

Segregation of sign clamor should be possible by isolating particular sound created by the bugs by registering specific highlights of every motivation and afterward they are contrasted and the standardized otherworldly elements (Potamitis et al., 2009). It was reported that the following spectral features could be used for discrimination: The dominant harmonic, linear frequency spectrum coefficients, and the Fourier transform (Mankin et al., 2009). In order to distinguish the features of background noise, such as clustering, insect-produced sound has been used. vector quantization and Gaussian combination models (Potamitis et al., 2009).

VI. ACOUSTIC WORLDLY EXAMPLE HIGHLIGHTS.

By consolidating temporal pattern features, insect detection accuracy can be improved. Many insects have predictable behavioral patterns. A portion of the examples with inadequate normalities were not described dependably by the PC programs, yet a few examinations observed that these examples were recognized as an explosion of motivations isolated by calm time frames s or more (Mankin et al., 2009). Insect feeding or movement resulted in a burst of approximately six impulses. To distinguish a specific insect sound from the background sounds, this phenomenon can be used as signal features. ID of transient highlights is simple for enormous and dynamic bugs. Union of blasts as a sign handling highlight empowers the evacuation of wind-prompted catching clamor or other foundation commotion like the sound signs delivered by bugs

Table-2

Advantages and limitations of modern methods of insect detection in stored food grains.

Insect Detection MethodsAdvantages		Limitations	References
1 Method based on conductance 1.1 Electrically Suitable for detecting hidden infestation, inexpensive conductive roller mill		Tedious as it examines a solitary grain, not reasonable for huge limit, unfit to distinguish the egg, hatchlings stages and dead bugs, not appropriate for low dampness content example	Brabec and co. 2012, 2017; Pearson and Brabec, 2007
2 Techniques based on smells	Dynamic headspace expands the awareness, high responsiveness	Costly, only works on adults, does not work on immature insects, and requires a skilled user	Laopongsit and others, 2014; Niu and co.,
2.1 Micro-solid phase extraction	Programmed, non-damaging, appropriate for buried pervasion and shape, quick, in-situ, reasonable for early recognition	Expensive, the device must be trained for a long time, complex data fusion techniques are used, expensive sensors are affected by the environment and need to be replaced after some time, and they cannot detect all insect species.	2000 by Magan and Evans; Wu and other, 2013;
2.2 Electronic Nose	m based strategies	Costly, unable to distinguish between insect species and detect dead and internal insects, and	Zayas and Flinn, 1998; Zhou and Wang, 2011. Miranda and other,
Electromagnetic spectrum	Appropriate for distinguishing proof and arrangement of assortments, bug invasion, grain staining, utilized for reviewing of horticultural produce	Costly, insufficient for insect egg detection, requiring skilled workers, and requiring safety measures to operate	Karunakaran et al., 2014, Vithu and Moses, 2016 2003; Kotwaliwale and others, Shuman and Epsky, 2001;
3.1 Imaging techniques in the visible range	Direct strategy, non-horrendous, high precision, sufficient to distinguish the inward and outside bugs, competent to recognize both live and dead bugs	Time-consuming, unable to classify the diverse variety of grains, pricey, and unable to identify insect development stages	Nanje Gowda and Alagusundaram, 2007; Flinn et al.,
3.2 Non-imaging methods 3.2.1 Electronic Grain Automatic, real-time monitoring, suitable for Probe Insect Counterbulk storage at any depth		Modern framework requires a gifted individual to work, costly, incapable to identify the dead bugs	Shuman and Epsky, 2001; Flinn et al., 2009
3.2.2 NIR Spectroscopy Rapid method, detect hidden insect infestation		Significant expense and required prepared individual, deficient to distinguish low degrees of invasion, requires adjustment and care of hardware	Neethirajan et al., 2007; Maghirang et al., 2003
4 Acoustic based method 4.1 Acoustic Detection is non-destructive, automatic, and can detect both internal and external insects. It has a high sensitivity, makes it suitable for making accurate decisions in silos, and can estimate the insect density.		Cannot detect eggs or insects that have died; requires a structure that is insulated from sound and vibration; detects within a suitable range; requires sophisticated equipment.	Eliopoulos et al., 2015; Fleurat-Lessard et al. 2006; Mankin & Hagstrum, 2012; Pearson and Brabec, 2007

Acoustic signals in biological materials are typically analyzed using gaussian windows (Mannell, 2008). Prior to processing, complex acoustic signals are filtered using a low-pass (LP), high-pass (HP), and band pass (BP) filter. During separating, a few frequencies are permitted to pass and others ought to be hindered. The majority of filters have a zone around the cut-off frequency where some frequencies can pass through.

According to Mannell (2008), this facilitates a smoother transition between the pass-band, or unattenuated frequencies, and the stop-band, or attenuated frequencies.
The term of R. ferrugineus sound motivation was 3-50 ms and 3.8 kHz top recurrence range (Potamitis et al., 2009). According to Mankin & Moore (2010), background noise typically had a high relative energy peak at low frequencies (below 1 kHz). The nature and degree of the background noise determine the filtering requirements. Signals with amplitudes above the threshold were eliminated following filtering. The sensor placements had an effect on the frequency and amplitude of insects. Before proceeding with signal processing, signals from one sensor can be subtracted from those from the other if multiple sensors are utilized.

A. *Acoustic Range Highlights*

Segregation of sign clamor should be possible by isolating particular sound created by the bugs by registering specific highlights of every motivation and afterward they are contrasted and the standardized otherworldly elements (Potamitis et al., 2009). It was reported that the following spectral features could be used for discrimination: The dominant harmonic, linear frequency spectrum coefficients, and the Fourier transform (Mankin et al., 2009). In order to distinguish the features of background noise, such as clustering, insect-produced sound has been used. vector quantization and Gaussian combination models (Potamitis et al., 2009).

B. *Acoustic Worldly Example Highlights*

By consolidating temporal pattern features, insect detection accuracy can be improved. Many insects have predictable behavioral patterns. A portion of the examples with inadequate normalities were not described dependably by the PC programs, yet a few examinations observed that these examples were recognized as an explosion of motivations isolated by calm time frames s or more (Mankin et al., 2009). Insect feeding or movement resulted in a burst of approximately six impulses. To distinguish a specific insect sound from the background sounds, this phenomenon can be used as signal features. ID of transient highlights is simple for enormous and dynamic bugs. As a signal processing feature, consolidation of bursts makes it possible to get rid of wind-induced trapping noise or other background noise that looks like insect sound signals.

VII. CONCLUSION

There are a number of options for identifying an infestation of insects in stored food grains. Visual inspection is one of the conventional methods; however, it is not suitable for bulk storage or the detection of hidden or low-density infestations; besides taking a long time.
While sampling probes and traps can be useful, they are time-consuming, tedious, only provide temporal data, and sometimes necessitate the destruction of samples.
The visual lure is a chemical-free method that uses light to attract insects, but its accuracy is influenced by the environment, has low sensitivity, and only provides information about adult insects. The pheromones method does not require sampling and can detect both internal and external insects.
However, due to the lack of information on various pheromone characteristics, its detection efficacy is limited to a small number of insect species. Berlese pipe strategy is quite possibly of the most well-known technique utilized in grain lifts, yet it is slow, unfit to identify stowed away pervasion and exactness relies upon bugs' size. In many developing nations, the uric acid detection method is officially accepted, but it only works on highly infested grains and has low sensitivity. The hidden infestation detector is a straightforward and inexpensive device that can only be used in very small quantities and is destructive. The majority of conventional methods are only effective for external detection.
The electrical conductance method, which was recently developed, can find the hidden infestation, but it can't find the egg and larval stages, needs a lot of moisture, and can only be used to characterize a single grain at a time. Although the solid phase micro extraction method with dynamic headspace has a high sensitivity, it can only detect adult stages and necessitates the expertise of a skilled individual for operation and analysis.
The fast, objective, and poison-free high technology of an electronic nose for insect detection is limited by the need for a large amount of experimental data to train the sensors; other than the sensors are impacted by the natural elements and furthermore their productivity diminishes over the long run. Machine Vision framework working in apparent reach is utilized for different applications in farming tasks and it shows the capacity to group the grains however distinguishing the dead and interior insects is costly and unfit.

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