AUTOMATED ELECTRONIC SENSING OF INSECTS AS A DATA SOURCE FOR SPATIAL ANALYSIS

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Detection and monitoring of stored-product insects is essential to an integrated pest management system. Spatial distributions of populations can minimize use of insect control methods based upon economic threshold analyses. The practical use of methyl bromide alternatives for insect control relies upon knowing the optimal times and places for their application in and around stored-products and upon having a means for measuring their effectiveness. Arrays of insect traps can provide input data to spatial analysis methods for generating contour maps of insect distributions. However, their use is limited by the time and effort required for accessing the traps, manually inspecting their contents, and accurately entering the insect counts into a spatial analysis database. Automated electronic sensing of insects can reduce these limitations by providing real-time data indicative of the presence or number of insects in the vicinity of each sensor.

Automated monitoring of live insects requires sensors to detect some component of their biological activity. The primary activities of insects are locomotion, feeding, and respiration. Since the magnitude of insects' activities are also affected by some environmental parameters (e.g., temperature and possibly humidity, ambient light and time of day), sensor data used to estimate populations may need to be adjusted by the outputs of other sensors measuring those parameters. Identification or differentiation of species may be important when various species with different destructive impacts are detected.

Locomotion and feeding activity of insects in stored-products can be detected with acoustic sensors. The sounds, generated by the insects' interactions with their substrate (usually the agricultural commodity), are detected when they exceed some specified amplitude threshold. Accordingly, the sound spectra are often more indicative of the commodity ("the drum") than of the insect species ("the drummer"). However, specific temporal patterns of sound activity may still be a marker to the unique biological activity of a particular species. False detections resulting from ambient noise can be prevented by raising the amplitude threshold level (effectively lowering the sensor sensitivity or its range of detectability), attenuating the noise (with external shielding or by being deep enough within the commodity), selective frequency filtering (when sounds and noise have different spectra), temporal pattern analysis, and masking (inhibiting sensor output when excessive ambient noise is detected). Population estimates based on quantification of acoustic activity are possible (Hagstrum et al, 1996) although there are many auxiliary factors that are currently being explored. These include species dependence (size and behavioral characteristics), environmental influences, sensor range, the method of quantifying the acoustic activity (what aspect of the sensor output signal is measured), and ensuring that the acoustic activity measurement varies with population density over the range of population densities of interest.

Insects in or around a commodity can also be counted as they pass by electronic sensors. It is preferable to count each insect only once when estimating populations, which can be accomplished by trapping or killing the insect when counting occurs. Presently available commercial traps rely on baits, pheromones, or behavioral characteristics to ensnare insects and the inclusion of electronic sensors can capitalize on this proven and accepted monitoring technology. The partial masking of an infrared beam by a falling insect in a pitfall trap has been used for counting insects in stored grain (Shuman et al, 1996). Since the sensor output signal is proportional to the fraction of the beam masked or the size of the insect silhouette, this can be used to implement an insect size threshold or help in species identification. However, since the shape of the insect is irregular, integration of the sensor information from orthogonal beams can increase the accuracy of size determination for a falling insect. In other contexts, parallel beams can also be used to resolve direction of motion, avoid multiple counts of a single insect, and provide insect size information. Other possible sensors for detecting insects are capacitive (an insect between two conductors alters their capacitance) and mechanical contact with a piezoelectric material. Flying insects can be monitored using an electrocuting grid outfitted with an inductive sensor to count the number of electrical discharges.

To ensure detection of insect activity, which can be erratic in nature, it is necessary for all sensors to monitor continuously. This can be achieved by having each sensor's processed data (e.g., an intrusion indication, numbers of sounds, or numbers of insects within a particular size range) being accumulated and stored at or near that sensor. In a large-scale system, the major cost may not be for the sensor hardware but rather for the means of getting the sensor array data entered into a spatial analysis computer for generation of contour maps. If the sensors are free-standing (and possibly battery powered), an attendent must go to each sensor and either manually enter its visually displayed data or perform an automatic download (e.g., using an optical connection to read and store a sensor's identity and its time-stamped data). Alternatively, all the sensors could be connected via a transmission network to the spatial analysis computer, allowing it to automatically read each sensor's accumulated data several times a day. This provides "real-time" data (population changes occur over days) and permits sensor placement in less accessible locations. A multiplexing tree transmission network was developed (Shuman and Nasah-Lima, 1996) which uses a minimal amount of cable to transfer data from up to a million addressable sensors to the serial port of the spatial analysis computer.

References

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