HIGH SCHOOL EDITION
Journal of Student Research
Volume 12 Issue 3 (2023)

Using Artificial Intelligence-Based Approach for Detecting Insects-Induced Grain Damage

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ABSTRACT

According to the Intergovernmental Panel on Climate Change, around 30% of global food production is wasted each year. Prevention strategies during post-harvest grain storage may reduce food waste and help distribute food surpluses more fairly globally, ultimately reducing global hunger. Insect damage is a major cause of post-harvest storage losses, resulting in both quality and nutritional loss to the grain. Recently, data-driven approaches have been used to enhance proper and efficient storage. The aim of this project is to investigate how artificial intelligence (AI) can be used to detect insect-induced grain damage during storage. This project used barley grain to test the experimental hypothesis that insect-related damage during grain storage can be detected by simultaneous imaging and AI-based analysis. An AI approach was developed using Python to build a prediction model. Data was collected by acquiring images of insect-induced damaged and undamaged grain. The AI-based model was highly (90%) accurate in identifying the damage caused by the insect based on the parameters defined in the algorithm. In summary, this innovative approach allowed us to identify grain damage, which, in the future, will help take necessary intervention(s) to prevent insect-induced grain damage and ultimately prevent loss during post-harvest storage.

Introduction

According to United Nations, the world population will increase to roughly 10 billion by 2050 which means more agriculture land is needed for increased cultivation to match ~50 % increase in food demand (Nations, n.d.). Over the years, technology has redefined farming and technological advances have revolutionized the agriculture industry in a way that has dramatically increased crop yield to a very high proportion (Goedde, 2020). Despite significantly increasing crop production globally we have not been fully successful in storing the post-harvest grain efficiently and in some cases, it accounts for ~40 % losses in grain during storage.

Figure 1. (**A**) Common Grain Weevil (size ~2.5-5 mm) (Britannica, n.d.). (**B**) Weevil shown in grain (Extension, 2023). (**C**) Silos to store food grains such as wheat, rice and barley to avoid wastage and grain damage (DoverMei, n.d.)

More recently, we have also learnt from our experiences such as from COVID-19 pandemic where shutdowns affected food grain availability globally more specifically in countries where agriculture production is historically low (Kumar, 2017) . Thus, there is a greater need for using efficient mechanisms by which we can store food grains for longer duration to match increasing food demand.

Post-harvest grain storage means grain is kept in a controlled environment in a storing chamber to minimize damage. Grain damage is caused by insects leading to complete destruction of grain in elevators or bins, where conditions are favorable, and the grain is stored for longer period. Grains are usually stored in silos where they can be significant insect infestation if conditions are favorable (Fig. 1). There are many types of grain insect species, the most common being: rice, granary (wheat and barley) and maize weevils (State, 2023). Grain weevils *a.k.a. Sitophilus granarius* is an insect that feeds on many types of grains. It causes a large amount of damage on stored grains. Adult weevils are around 2.5-5mm long (Figure 1). Depending on their age the weevil's color is from light-brown to black. Young individuals tend to be light-brown while adults are black (Food, n.d.)). Grain Weevils tend to grow from factors such as: air humidity, temperature, and food. Grains Weevils are known for their rapid fertility, a female weevil can grow at least 9 eggs in a day making it to150 eggs in a lifetime. At a temperature of 12 degrees Celsius they can usually last about 115 days without food (Boniecki, 2020). There are many methods of artificial intelligence in agriculture: Crop Yield Prediction and Price Forecasts which outputs yields and forecast prices; intelligent spraying which is for weed detection and precise herbicide application; predictive insights which is the right time to sow the seeds and enhance productivity; agricultural robots which is using autonomous robots, and harvesting huge volumes of crop; crop and spoil monitoring which is for crop health and diagnosis of pests; disease diagnosis which is a type of treatment; the last and most effective one is Post-harvest storage which is real time monitoring, identifies pests, treats pests, and is kept under temperature and humidity. With the emerging technologies such as high-quality imaging and sensors coupled with artificial intelligence driven approaches (as depicted in Figure 2), it is now believed that post-harvest grain damage can be minimized. Thus, this current work was carried out to use AI technology in assessing images and predict accurately the damage caused during post-harvest storage.

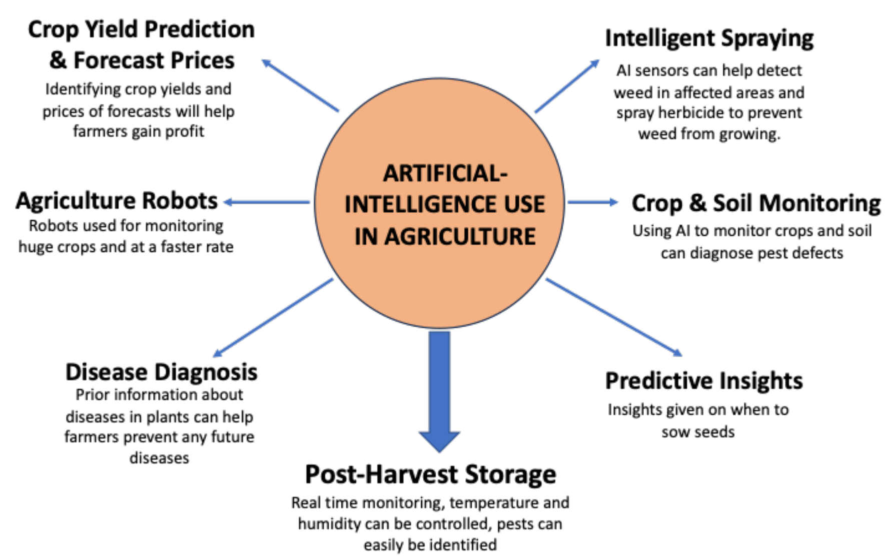

Figure 2. **Application of artificial intelligence in agriculture**. As shown in the schematic post-harvest storage has great potential to use Artificial Intelligence (AI) to prevent any infestation of crops/grains; modified from (Wipro, 2019).

Material and Methods

Approach

- This project used barley grain (widely used globally) to test the experimental hypothesis that insect-related damage during grain storage can be accurately detected by imaging and using AI-based approach (depicted in Figure 3).
- A given amount of barley was stored in containers at conditions required to cause grain damage (45-60 days) (protocol provided by Dr. CB Singh, Associate Professor and Senior Research Chair, University of Lethbridge, AB as per Canadian Grain Research Laboratory). While undamaged/healthy grain was purchased from the grocery store for taking pictures.
- A training set was designed with 200 images captured with an iPhone 13 over a period of 2 days to capture both healthy and damaged barley grain.
- Images were marked individually (as shown in the Figure 4) to capture weevil and the damage caused by the insect by drawing a region of interest using National Institute of Health open-source image analysis software ImageJ.
- AI model was trained to generate a predictive algorithm using Python and convoluted neural network that predicted how well the model is working.
- Train learning curve were calculated from the training dataset that gave an accurate idea of how well the model is learning.
- Validation learning curve were calculated from a hold-out validation dataset that gave an idea of how well the model is generalizing.
- Testing data set, a total of 300 images were then used to test for accuracy in results using AI-based approach.

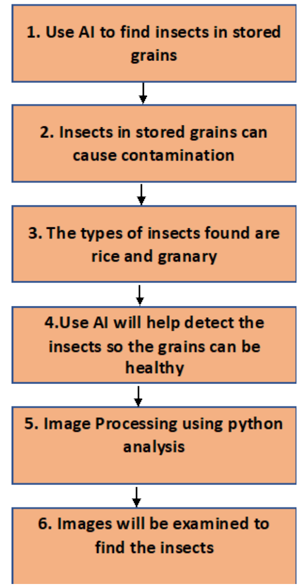

Figure 3. Schematic showing the approach used in this study.

Results

Barley grain was stored as described in the approach section. Images of both healthy and damaged grains were captured using an iPhone 13 (Figure 4). The AI-based model exhibited a remarkable accuracy rate of 90% in identifying the damage caused by insects, based on the predefined parameters in the algorithm (Figure 5).

Even though there are many uses of AI in agriculture its utility can be applied in post-harvest storage, where the factors of real time monitoring and controlling the temperature and humidity can help prevent any grain damage. Upon analyzing the undamaged grains, it was observed that weevils were found in the grains after being left for over a period of 45-60 days. The AI model successfully classified the presence of weevils in the grains and accurately distinguished between damaged and undamaged grains (Figure 5). Since weevils are not easily detected by humans, AI proves to be a valuable tool in identifying infested grains.

Figure 4. Images of undamaged and damaged barley grains. Healthy (A, undamaged) and damaged (B) barley was imaged using an iPhone 13. Region of interest were drawn (in red) around weevil, undamaged (C) and damaged (D) barley.

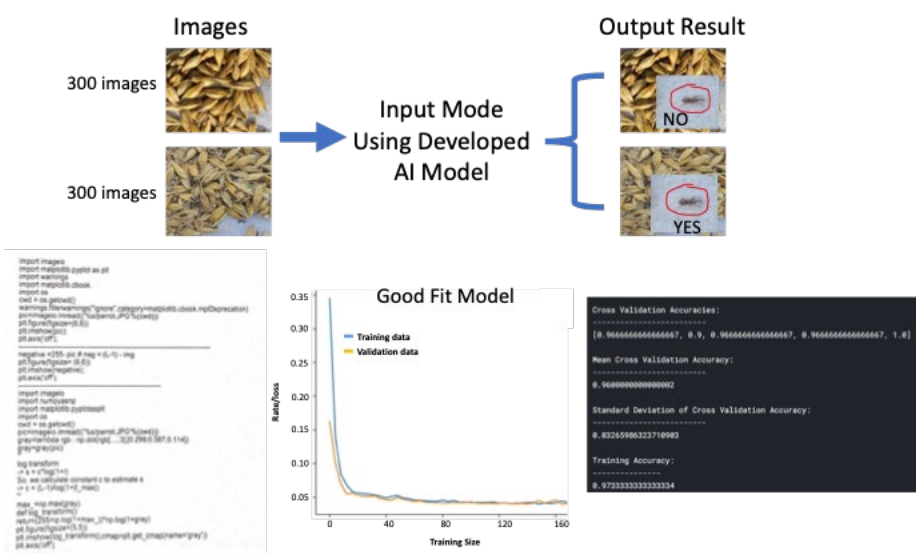

Figure 5. 200 images were taken to train the model while 300 images were taken to test and validate the model as shown above. The model accurately predicted healthy vs damaged grains as per the python program which also revealed a good fit for the model. Testing of 300 images per group revealed that the AI-model used was 90% accurate, helping in classifying which grains were damaged and which were not. Out of 600 images that were entered as an input, the model identified, these images correctly at a rate of 9 in 10 images. Python Programming Code Used from Jupyter lab to help determine weevils in grains.

The AI approach used in this project, developed using Python and a convolutional neural network, demonstrated its effectiveness in accurately detecting insect-induced grain damage. The model was trained on a set of 200 images, consisting of both healthy and damaged barley grains, to generate a predictive algorithm. Learning curves were calculated from the training dataset to assess the model's learning progress, and a hold-out validation dataset was used to evaluate the model's generalization. The final testing dataset comprised 300 images, which were used to assess the accuracy of the AI-based approach.

Discussion/Conclusion

The high accuracy achieved by AI models in identifying insect-induced grain damage opens up significant possibilities for the improvement of post-harvest storage practices. The utilization of AI-based tools enables the development of efficient systems that can effectively detect and mitigate grain damage caused by insects. This breakthrough has the potential to greatly reduce grain wastage and make a substantial contribution to global food security.

By employing AI in grain storage, we can implement early intervention and preventive measures, leading to minimized losses and preserved nutritional quality in stored grains. The ability to detect damage early on allows for prompt action, preventing further deterioration and ensuring that the grains remain suitable for consumption. This not only saves valuable resources but also safeguards the availability of nutritious food for communities worldwide.

In addition to its immediate benefits for grain storage, the integration of AI-driven technologies holds broader implications for sustainable agriculture and poverty alleviation. By effectively detecting and addressing insect-induced grain damage, farmers and agricultural stakeholders can enhance their grain preservation techniques, resulting in increased food availability. This, in turn, has a positive impact on the livelihoods of vulnerable populations, as it strengthens their access to nourishing food sources.

Furthermore, the reduction of grain losses during storage through the implementation of AI technologies contributes to a more equitable distribution of food surpluses on a global scale. By preventing spoilage and wastage, we can ensure that food resources are utilized efficiently and reach those who need them most. This approach plays a crucial role in alleviating hunger and working towards the achievement of the Sustainable Development Goals, particularly Goal 2: Zero Hunger.

Overall, the application of AI in identifying and mitigating insect-induced grain damage has transformative potential for post-harvest storage practices. It not only minimizes losses and enhances grain preservation but also addresses larger challenges such as food security, sustainable agriculture, and poverty alleviation. By leveraging AI-based tools, we can create a more sustainable and equitable food system that benefits communities worldwide.

Future Directions

While this study demonstrates the efficiency of AI-based approach for detecting insect-induced grain damage, further research is warranted to explore and optimize the application of AI in post-harvest grain storage environment. Future investigations could focus on expanding the dataset and refining the AI model to improve accuracy and robustness. Additionally, exploring the potential of real-time monitoring systems utilizing AI algorithms could enable prompt detection of insect damage and facilitate timely interventions. Furthermore, integrating AI with other emerging technologies, such as Internet of Things (IoT) sensors and blockchain, could enhance traceability and transparency in the grains.

Acknowledgements

I would also like to thank North Penn High School and my mentor Dr. Chandra Bhan Singh for providing resources and guidance for this research.

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