Mechanizing Sunflower Seed Count and Insect-damage Detection

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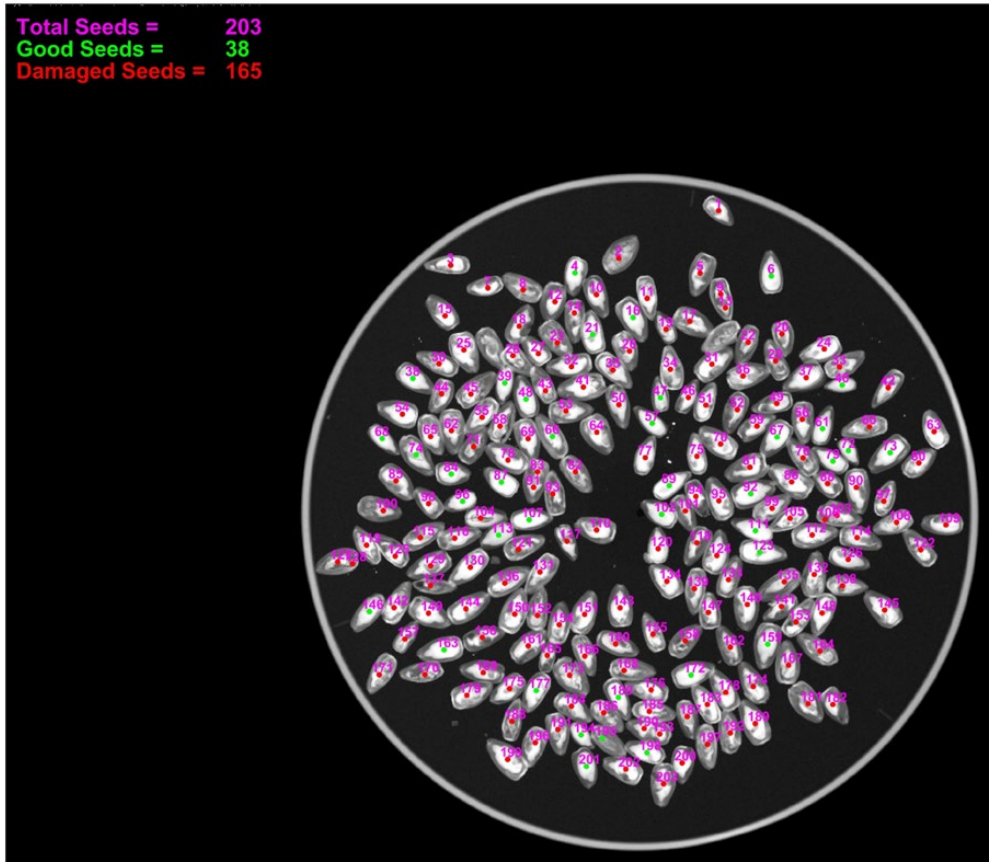
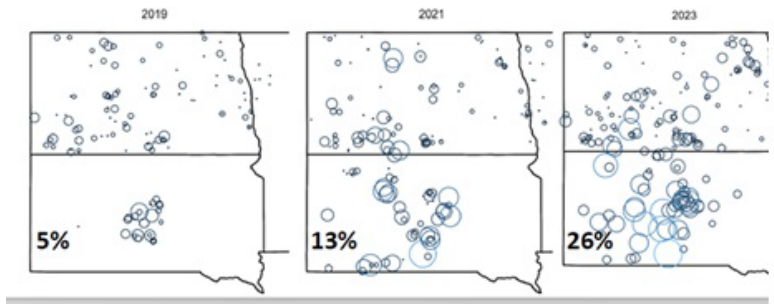


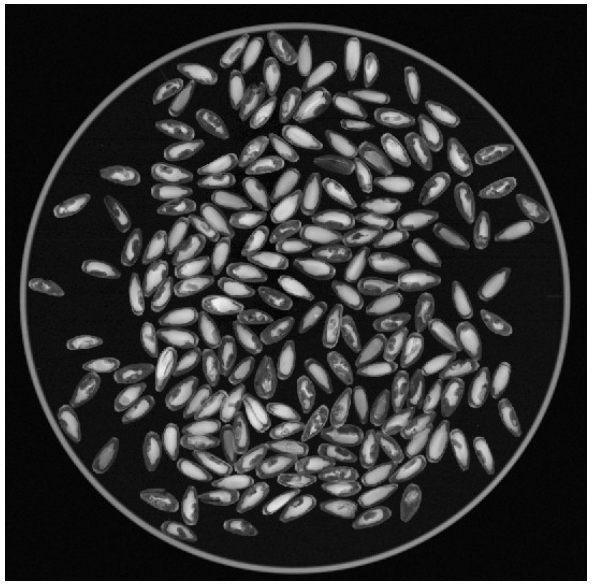
Accelerate development of insect resistant cultivars and management strategies

- Challenge: Insect damage is causing economic losses
- Approach:
  - Insect resistant cultivars
  - Effective management strategies
- Breeding trials and field experiments
  - Acquiring x-ray images of seed samples
  - Manual counting requires labor hours and prone to human bias
- Objective: Automate to reduce labor hours and eliminate human bias

- Red seed weevils most damaging pest
- Up to 76, 90% damage in 2021, 2023
- SD ≈ 3X times damage in ND



Prasifka et al. [unpublished data]

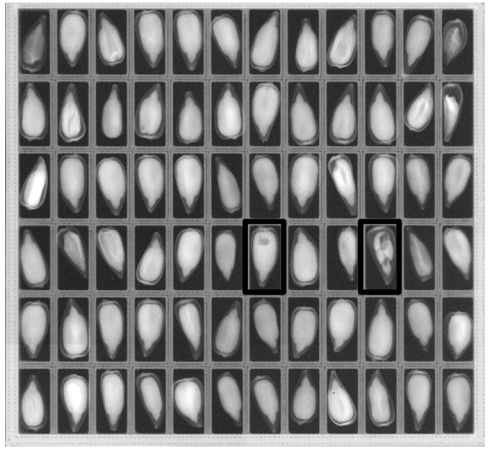


Mathanker and Prasifka [unpublished data]

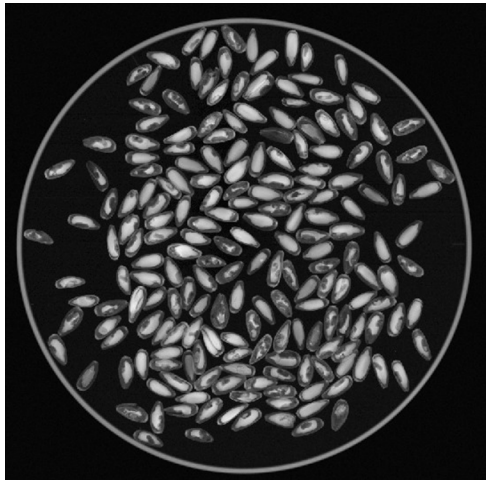
Available methods to automate insect-damage detection requires positioning of seeds

- Sample preparation (seed positioning) negates the benefit the automation offered

- Objectives:
  - Count seeds in an x-ray image of a seed sample of 200 sunflower seeds that has
    - ➢ randomly oriented seeds,
    - ➢ overlapping seeds, and
    - ➢ unevenly distributed seeds.
  - Detect insect-damaged seeds



Pearson et al. 2014
[doi:10.13031/aea.30.9942]



Mathanker and Prasifka [unpublished data]

Characteristics of sunflower seeds damaged by the insects

Red SF Seed Weevil

Banded SF Moth

SF Moth

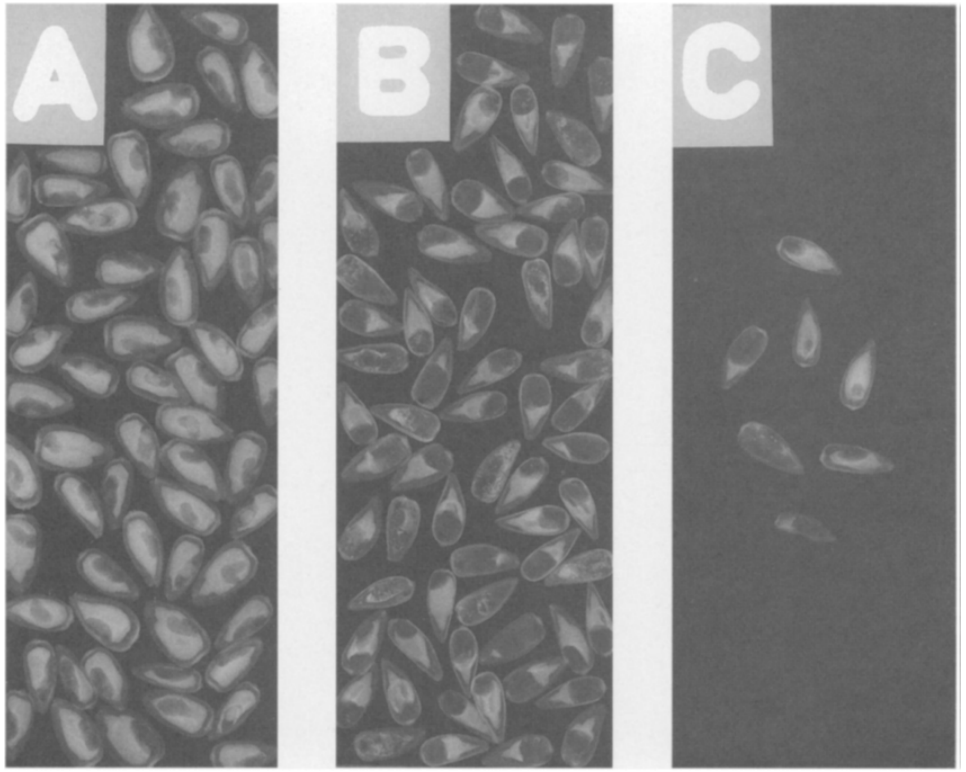
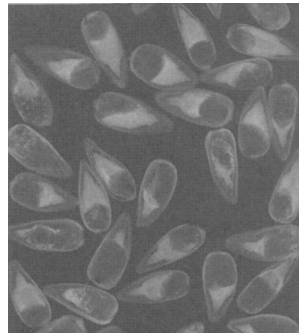
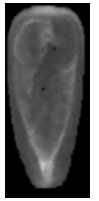
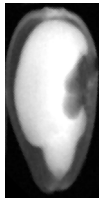
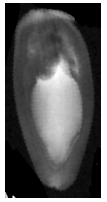
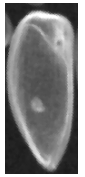
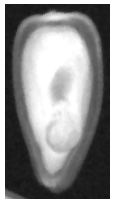


Table 1. Characteristics of achenes infested by red sunflower seed weevil, banded sunflower moth and sunflower moth.

Insect	Pericarp	Kernel
Red sunflower seed weevil	An exit hole on the lateral side, ⅛ to ½ of the distance from the broad, distal end to the proximal end. Edges of the holes irregular (Fig. 1a).	Part of the kernel eaten. Distal end of the kernel remaining. Frass always present on the kernel surface (Fig. 1d).
Banded sunflower moth	A feeding hole on or near the distal end. Edges of the holes smooth and the holes larger than those of the red sunflower seed weevil (Fig. 1g). Silken sheets usually around the hole (Fig. 1g).	Part or all of the kernel consumed. Distal end of the kernel always absent. If the kernel only partially consumed, frass usually absent (Fig. 1e). If the kernel entirely consumed, frass sometimes present.
Sunflower moth	A feeding crack extending from the distal to the proximal end (Fig. 1c).	Part or all of the kernel consumed. Part of the kernel consumed variable (Fig. 2c).

Peng and Brewer (1995) https://digitalcommons.unl.edu/entomologyfacpub/231

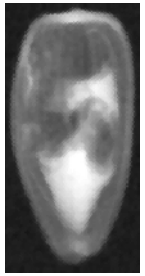
Characteristics of sunflower seeds damaged by the insects

Good seed (A)	Red Sunflower Seed Weevil damaged seed (B)	Banded Sunflower Moth damaged seed (C)	Under-developed seed (D)	Unfilled seed (E)
	 Peng and Brewer (1995)	 Peng and Brewer (1995)	 (D1)	 (E1)
			 (D2)	 (E2)
			 (D3)	 (E3)

Mathanker and Prasifka [unpublished data]

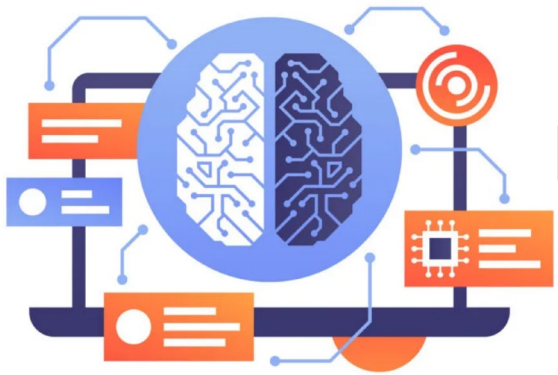
Machine Learning Model: Trained on 15 seed-sample images (3,000 sunflower seeds)

Good:
More kernel area

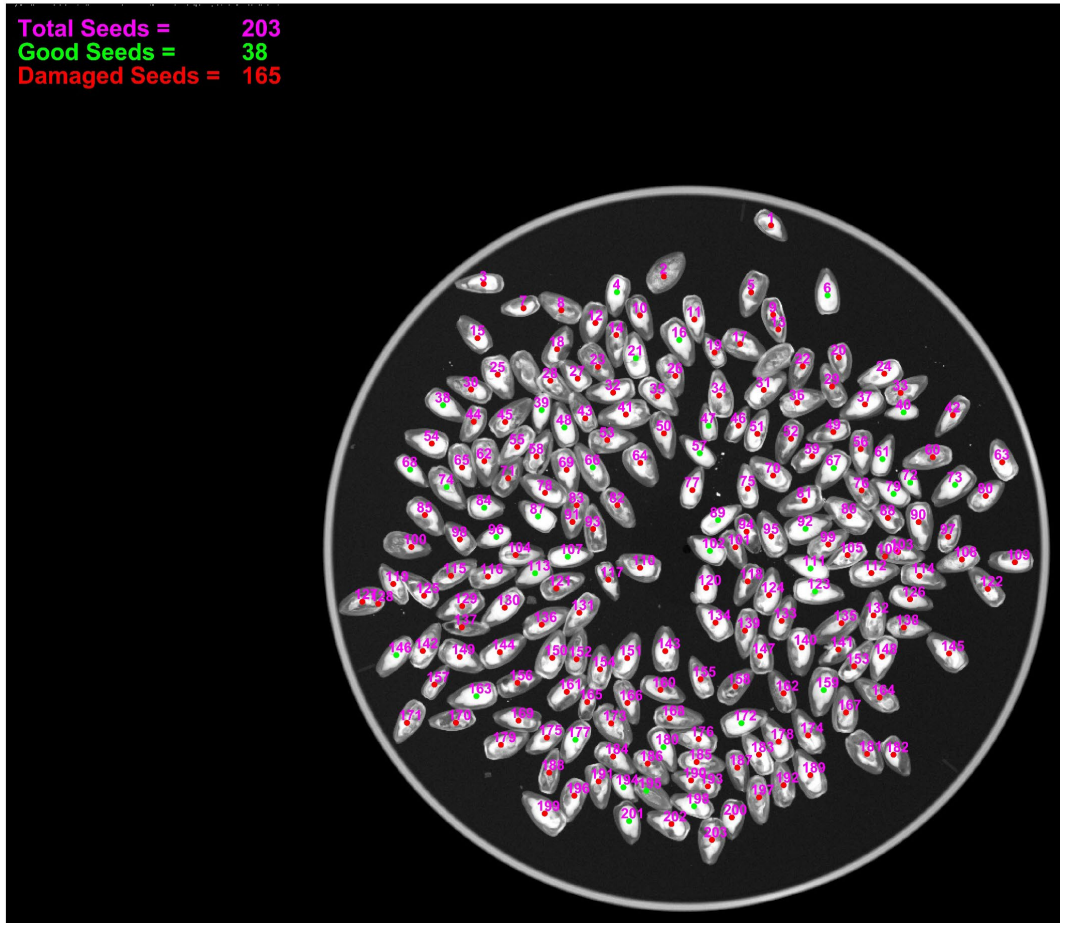


Damaged:
Less kernel area

All 15 images



https://www.krasamo.com/machine-learning-models/

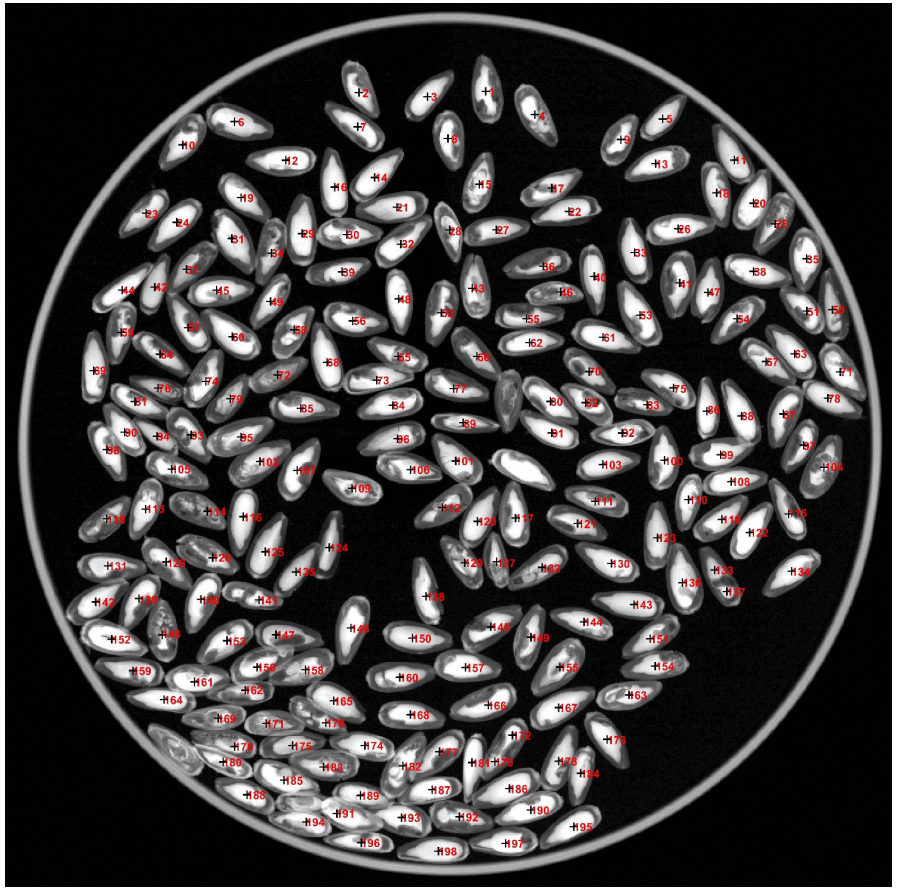


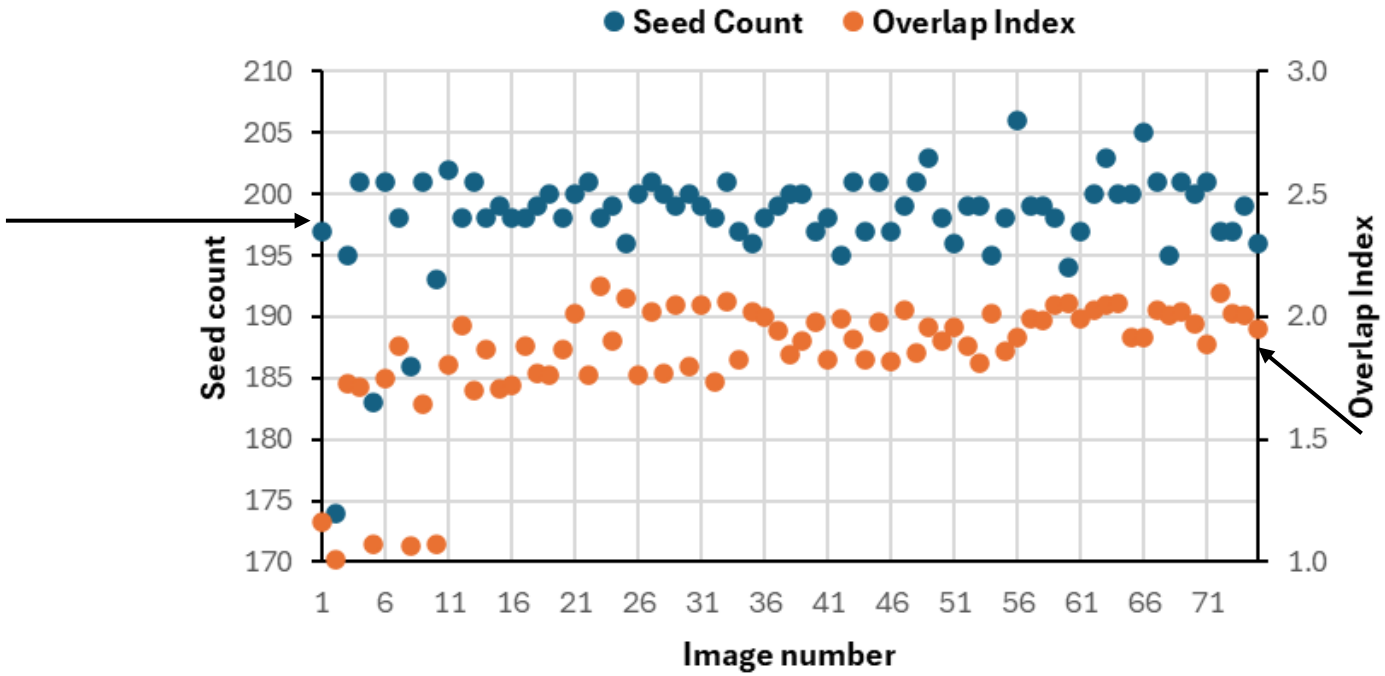
Mathanker and Prasifka [unpublished data]

Mathanker and Prasifka [unpublished data]

Counting seeds in a seed sample of 200 seeds:

Good image contrast and Limited overlap (touching pericarp)

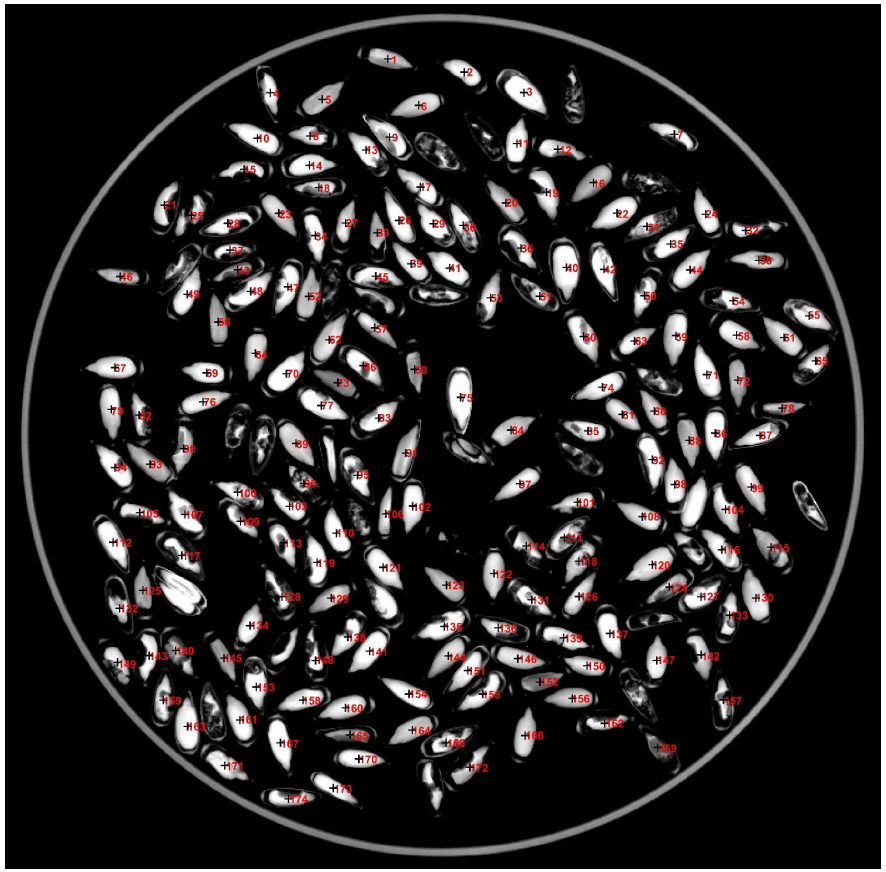


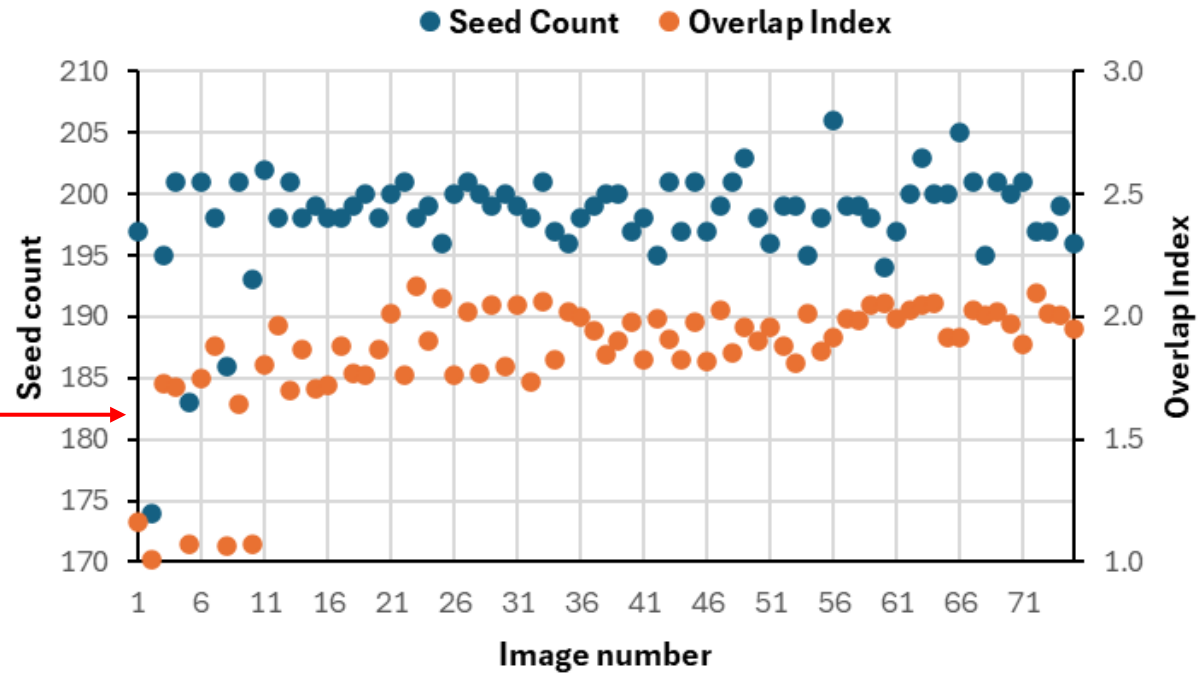


Mathanker and Prasifka [unpublished data]

Counting seeds in a seed sample of 200 seeds:

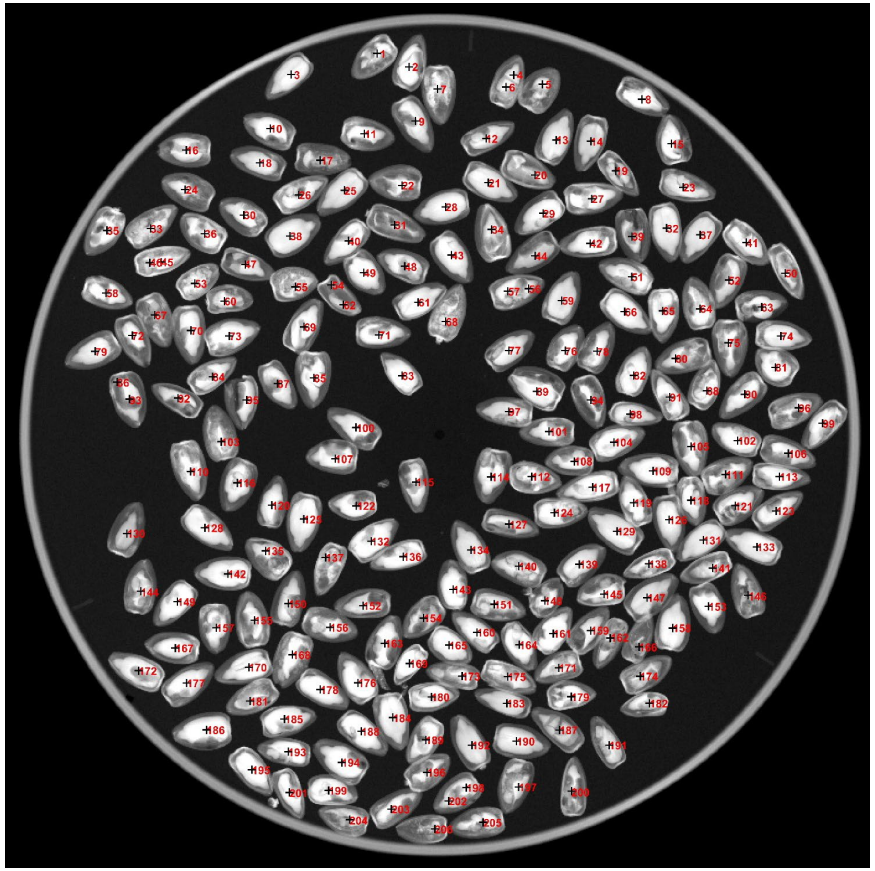
Undercount (Poor image contrast)

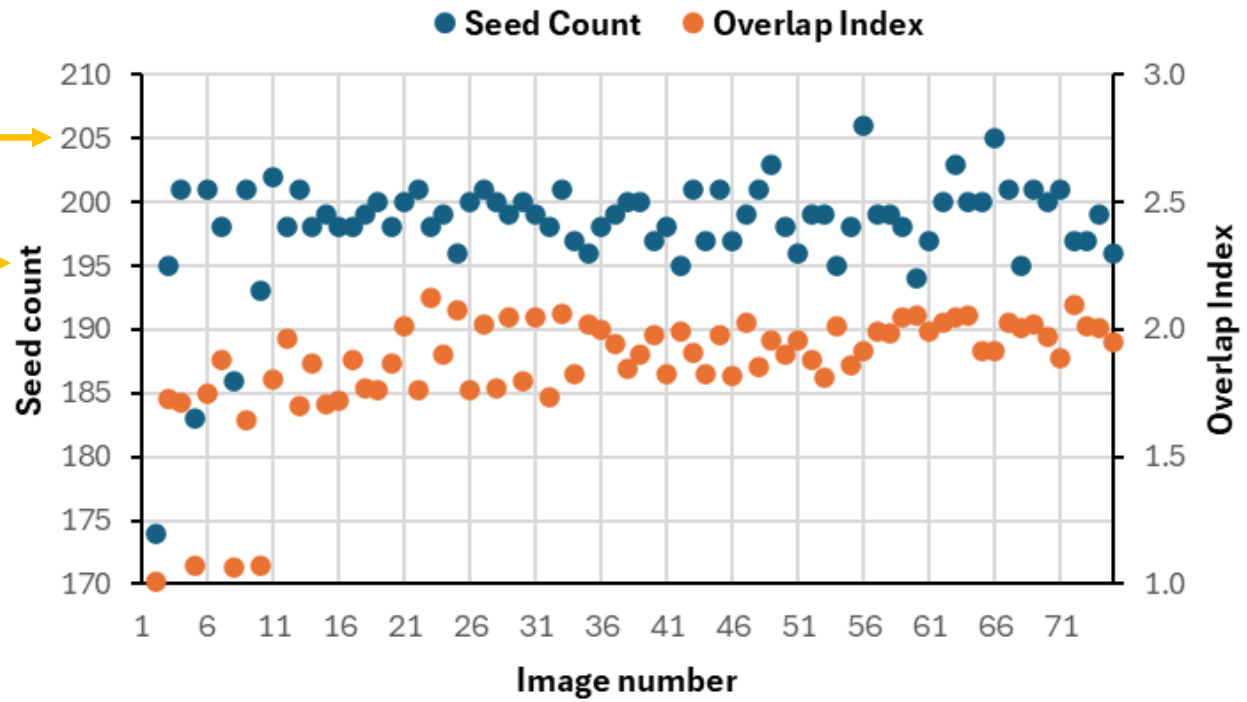




Mathanker and Prasifka [unpublished data]

Counting seeds in a seed sample of 200 seeds:
Slight Overcount/Undercount (unique damage/seed types)

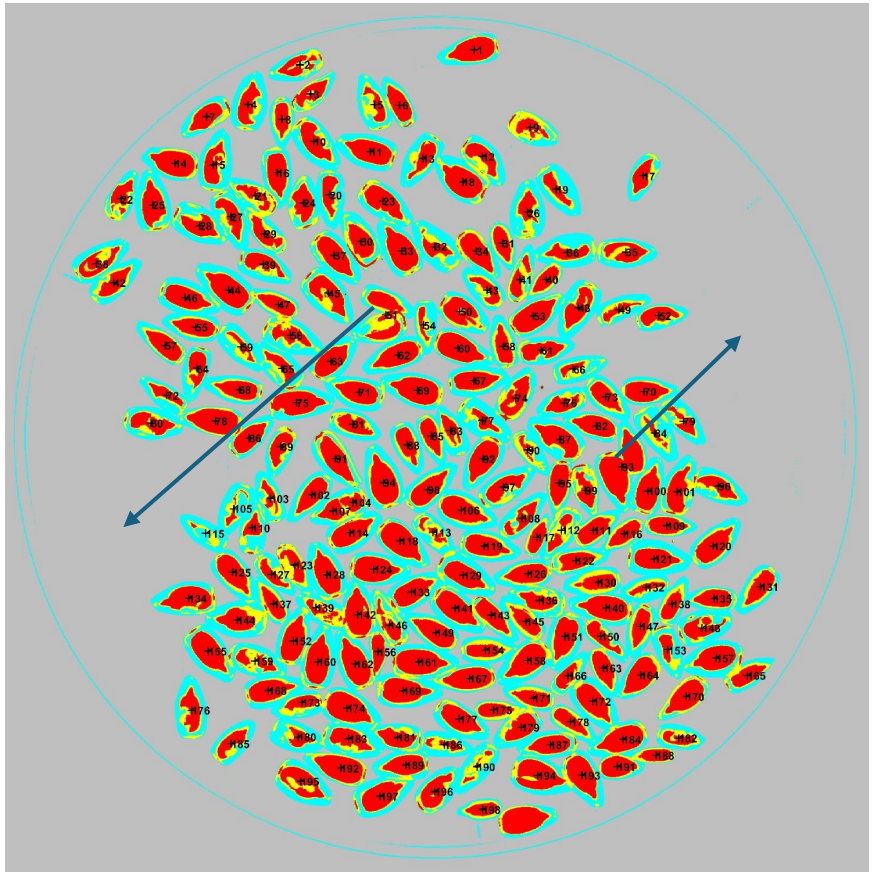


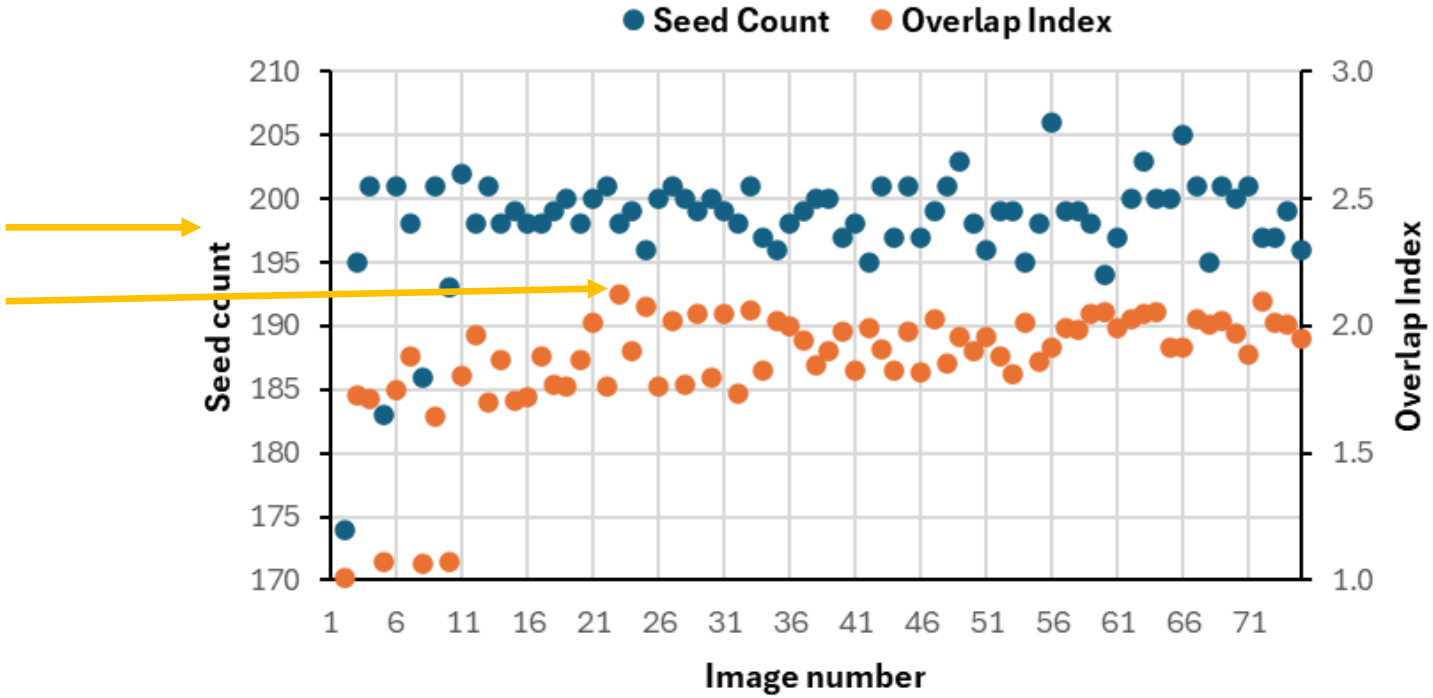


Mathanker and Prasifka [unpublished data]

Counting seeds in a seed sample of 200 seeds:

Slight Undercount (Excessive Overlap: touching kernels)

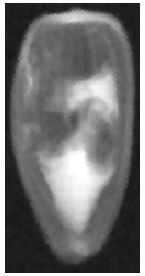




Mathanker and Prasifka [unpublished data]

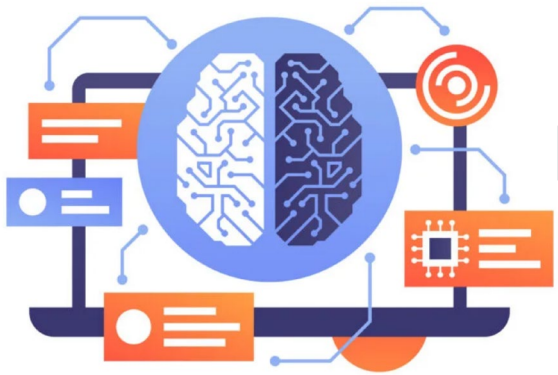
Machine Learning Model: Trained on 15 seed-sample images (3,000 sunflower seeds)

Good:
More kernel area



Damaged:
Less kernel area

All 15 images



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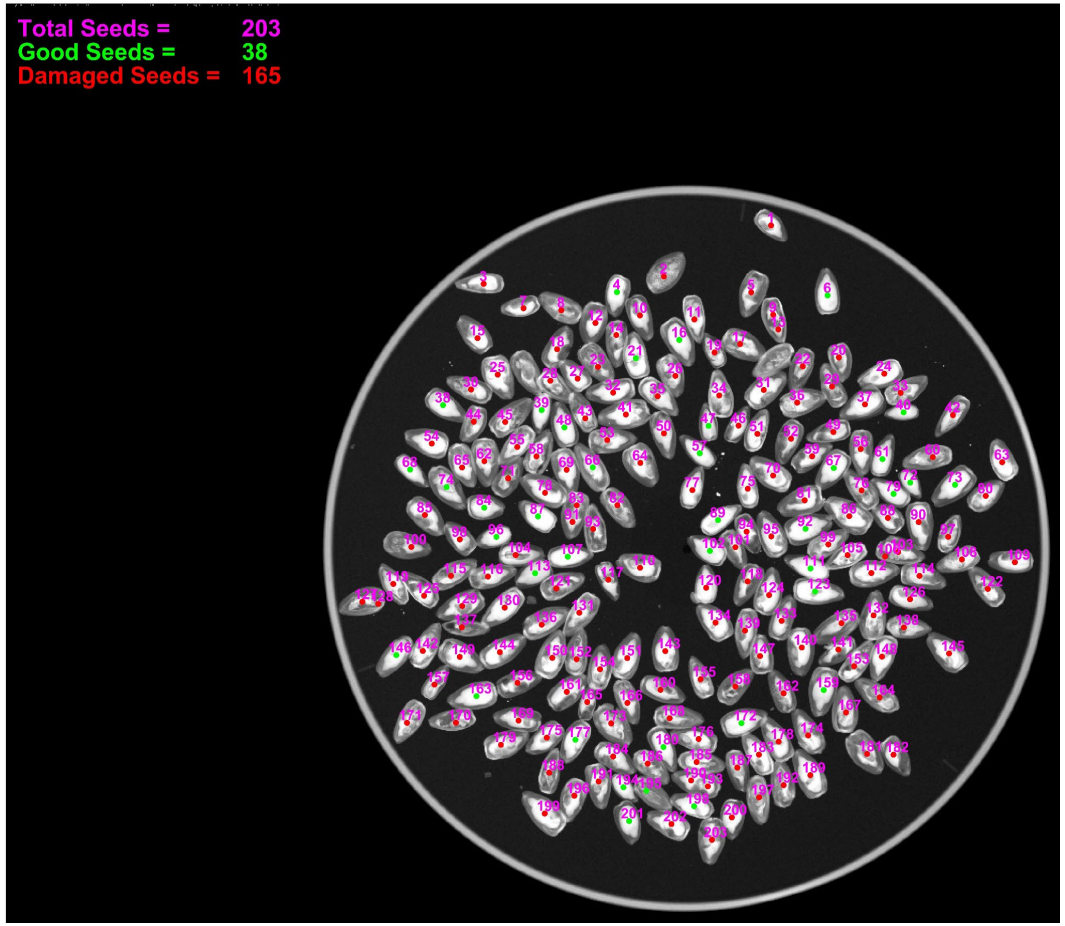
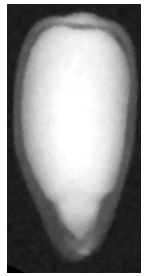


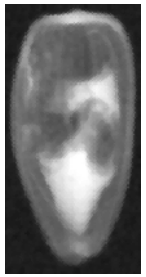
Mathanker and Prasifka [unpublished data]

Mathanker and Prasifka [unpublished data]

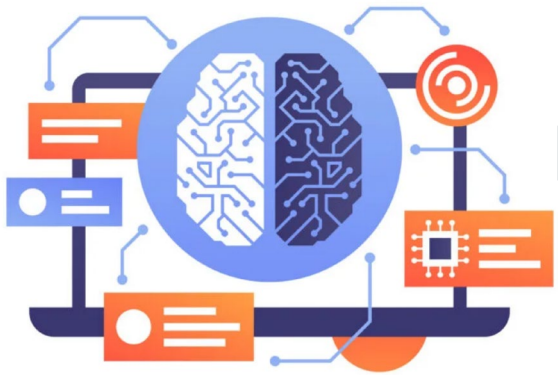
Machine Learning Model: Trained on 15 seed sample images (2,996 seed images)

Good (0):
More kernel area





All 15 images



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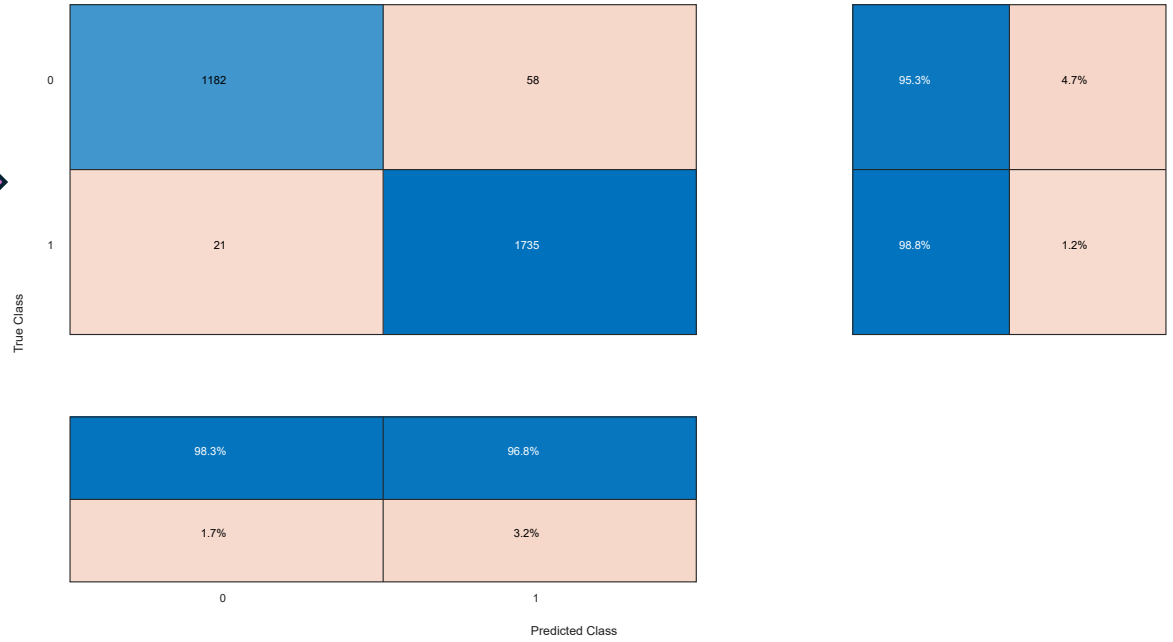


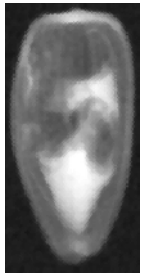
Damaged (1):
Less kernel area

Mathanker and Prasifka [unpublished data]

Machine Learning Model:

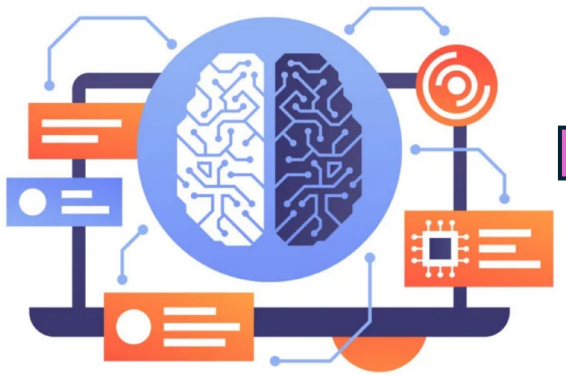
Trained on 2023 experiment to predict insect-damage for 2024 experiments

Good (0):
More kernel area



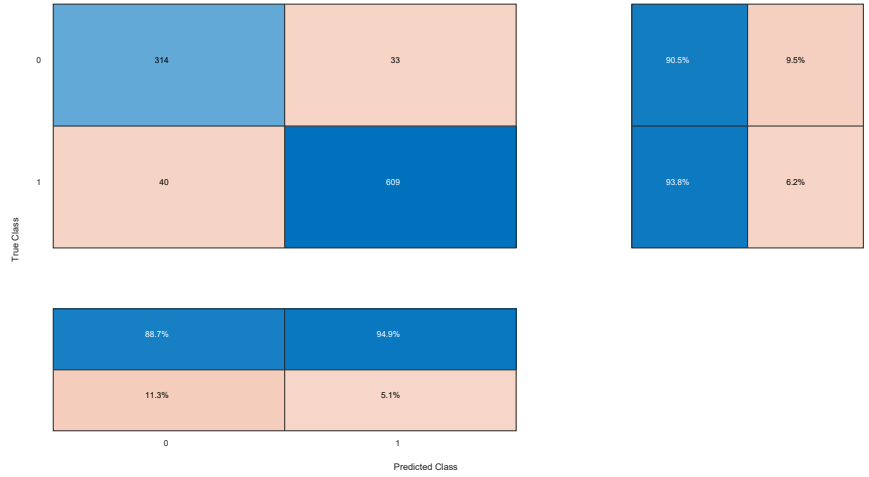
Damaged (1):
Less kernel area

DLRF2023
(5 images)

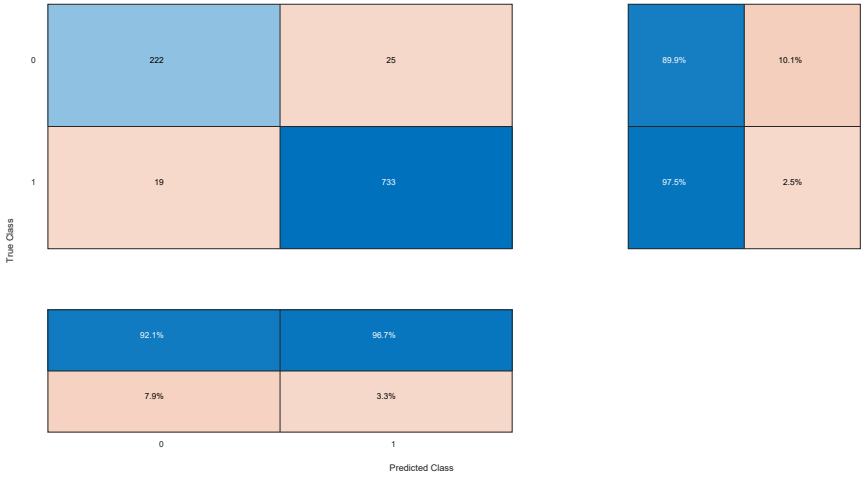


https://www.krasamo.com/machine-learning-models/

DLRF2024



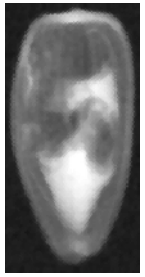
24SturgisWRRF



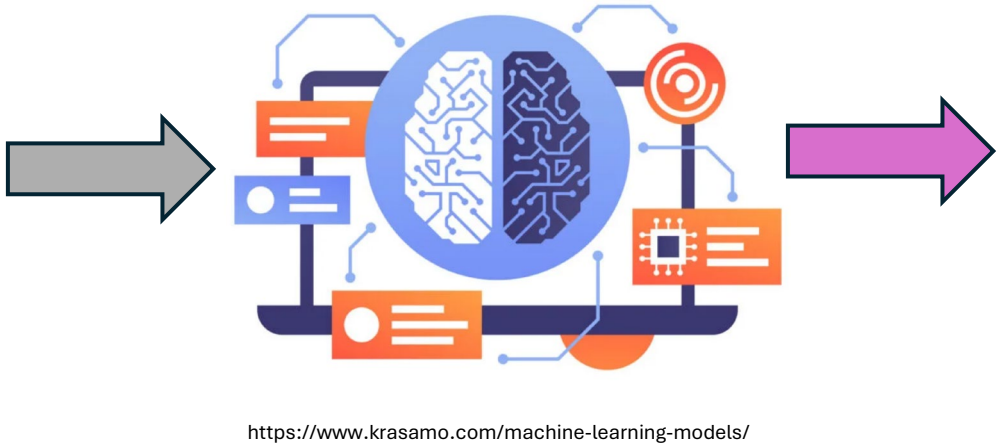
Mathanker and Prasifka [unpublished data]

Machine Learning Model: Model trained on one dataset to predict insect-damage in unseen images

Good:
More kernel area



15 or various 5 images



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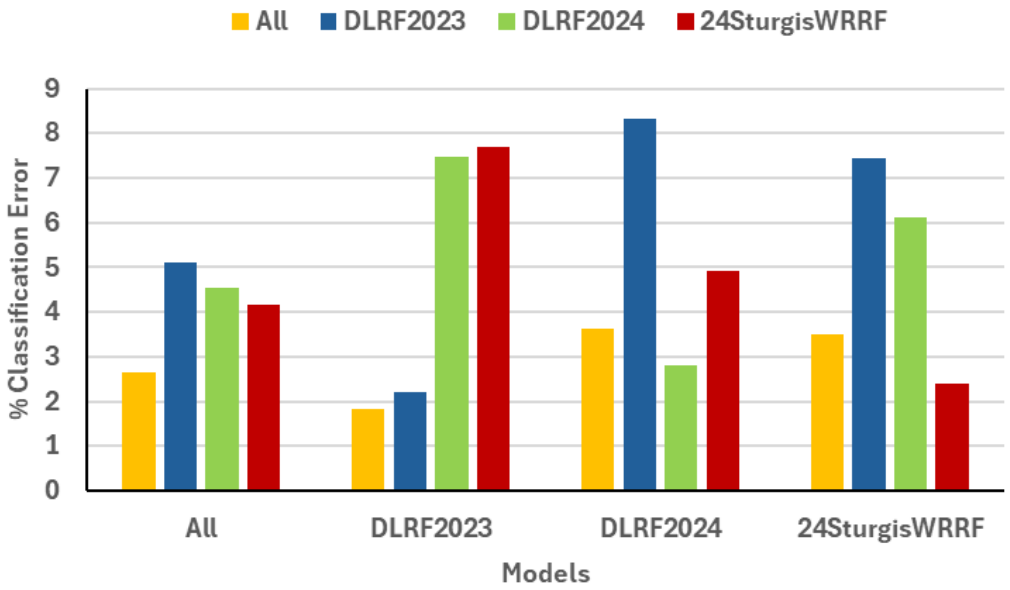
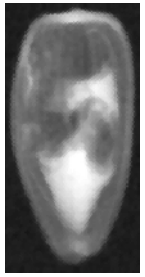


Mathanker and Prasifka [unpublished data]

Damaged:
Less kernel area

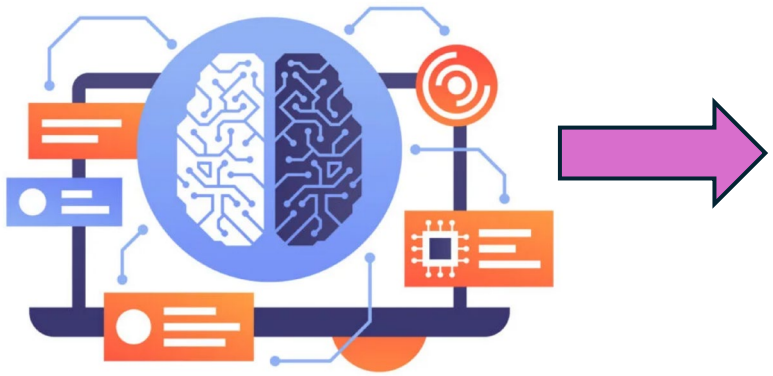
Machine Learning Model: Developed model predicted insect-damaged seeds with comparable accuracy

Good:
More kernel area



Damaged:
Less kernel area

15 or various 5 images



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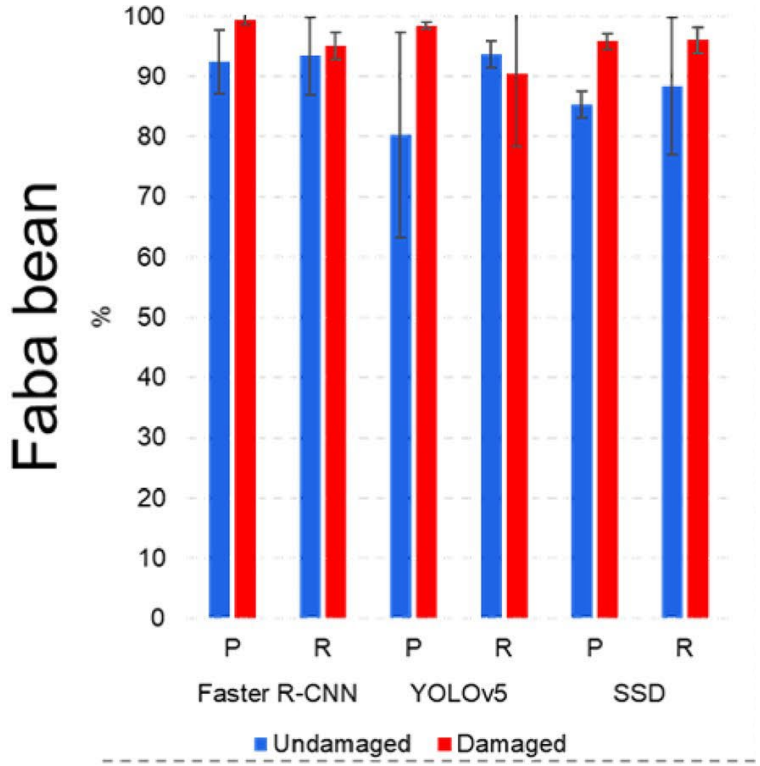
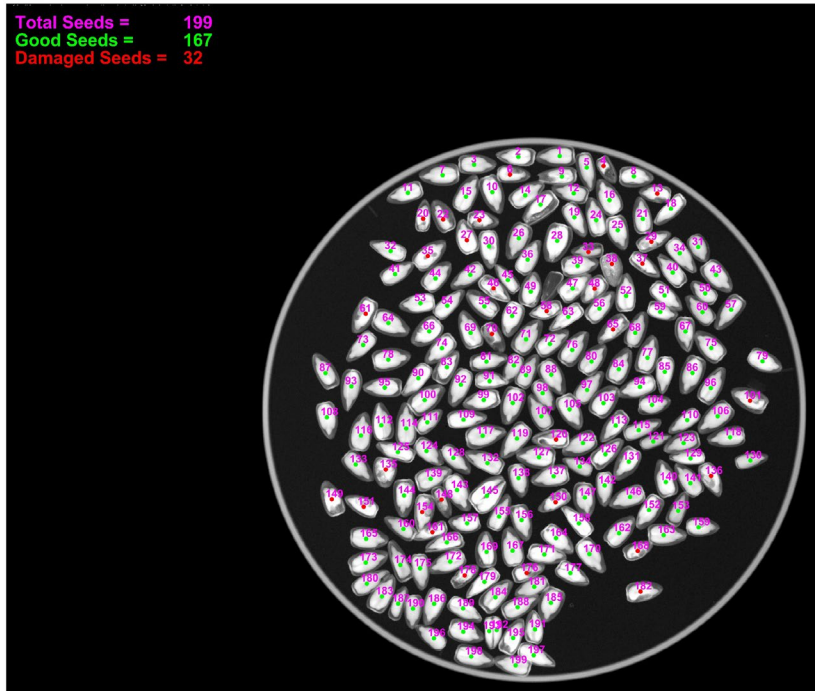


Hamady et al. 2024

Conclusions

- A **Machine Learning Model** to predict insect-damaged seeds is developed that can use a seed-sample x-ray image with
  - randomly oriented seeds,
  - overlapping seeds, and
  - unevenly distributed seeds.
- Preliminary results shows promising results
- Future work:
  - Reduce Missed and Part counts
  - Improve seed count: ± 2 seeds per 100 seeds
  - Train the Machine Learning Model: more than 75 seed-sample images (15,000 seeds)
  - Reduce classification error: less than 5%
  - Develop **Deep Learning Model**:
    - Pro: more accurate, may predict the insect that damaged the seed
    - Cons: thousands of images needed for training



Mathanker and Prasifka [unpublished data]