Neural Networks:

How Software can Learn from Experience

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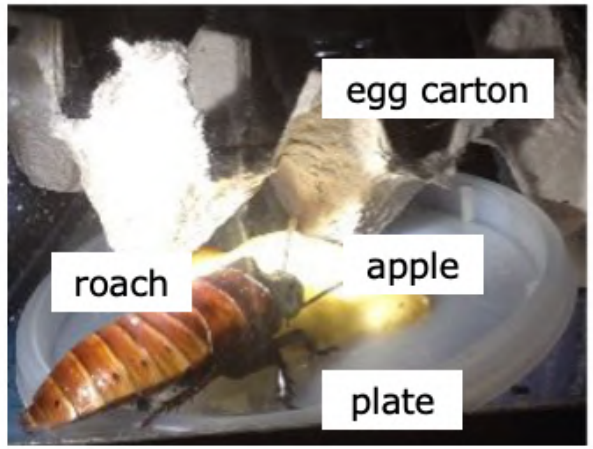
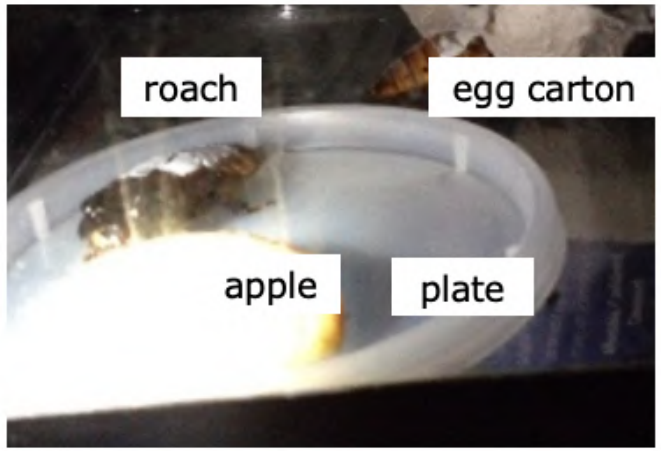
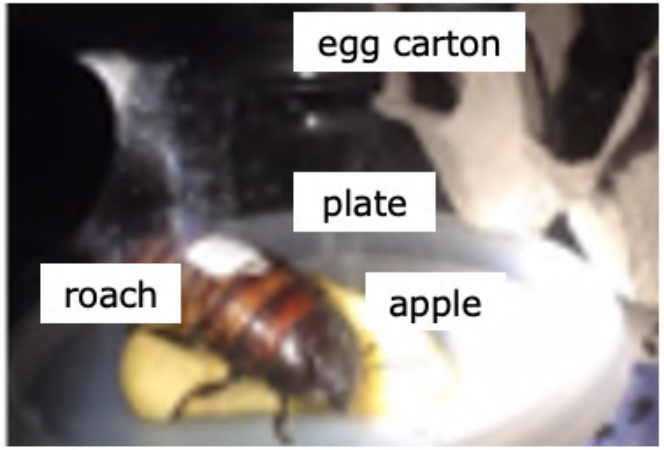
Motivation

Image Analysis for Biological Experiment

- Analyzed ~24000 images for biological experiment
  - Images included plate, food, and egg cartons
  - 465 images had cockroaches







Identifying cockroach images was a tedious process

Image Analyzing Neural Network

Neural network (NN) → automated image analysis (faster)

- Trained NN with example images: 350 positives (roaches), 1500 negatives (no roaches)

Positive Image

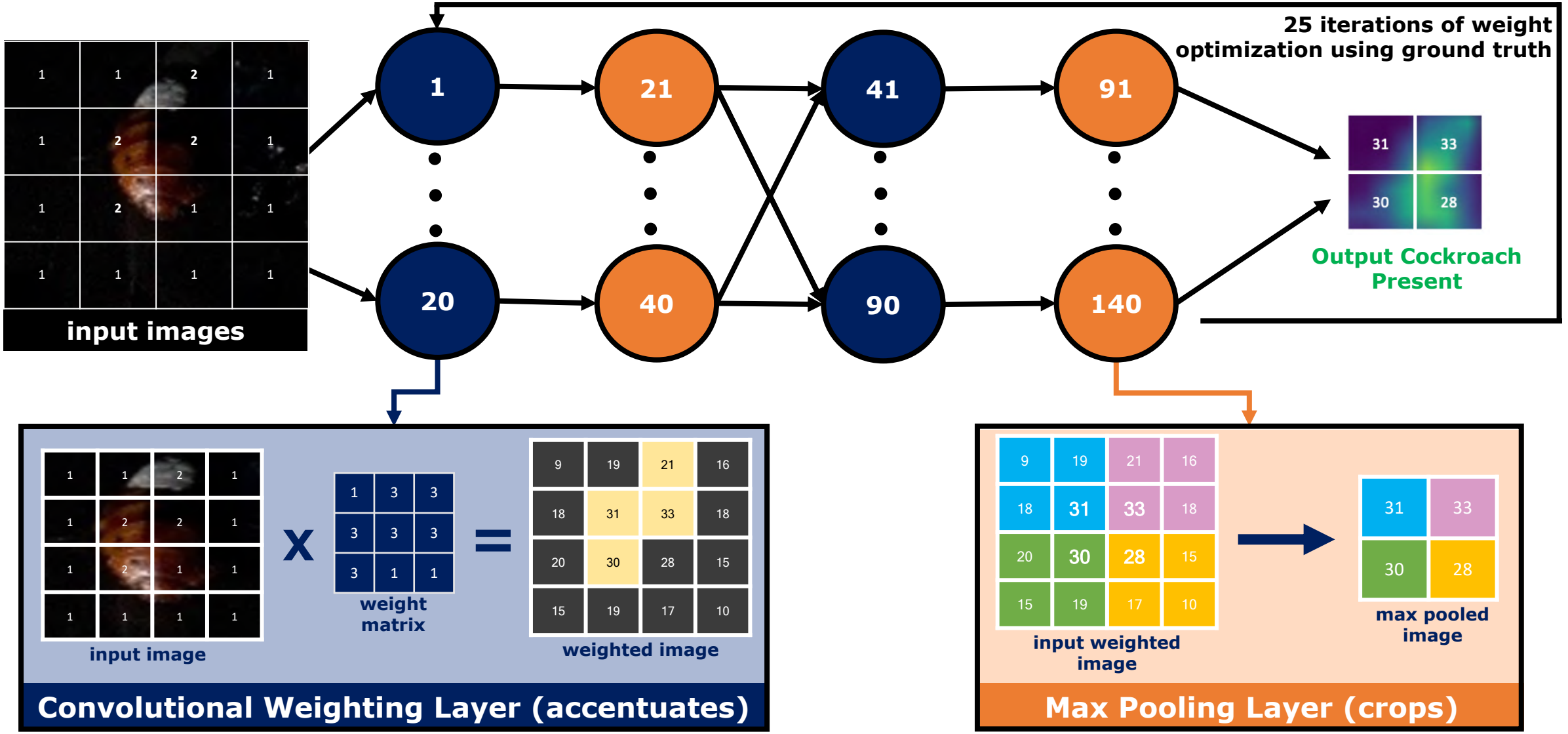
Negative Image

- Images subtracted from previous to remove still background objects

Subtracted Positive Image

Neural Network Structure

Repeated Weighting of Image Pixel Values



Research Question

Do NNs detect key features visible to humans?

- Trained NN was validated with 23,244 new images
- Detected roaches with 96% accuracy (calculated with Metric)

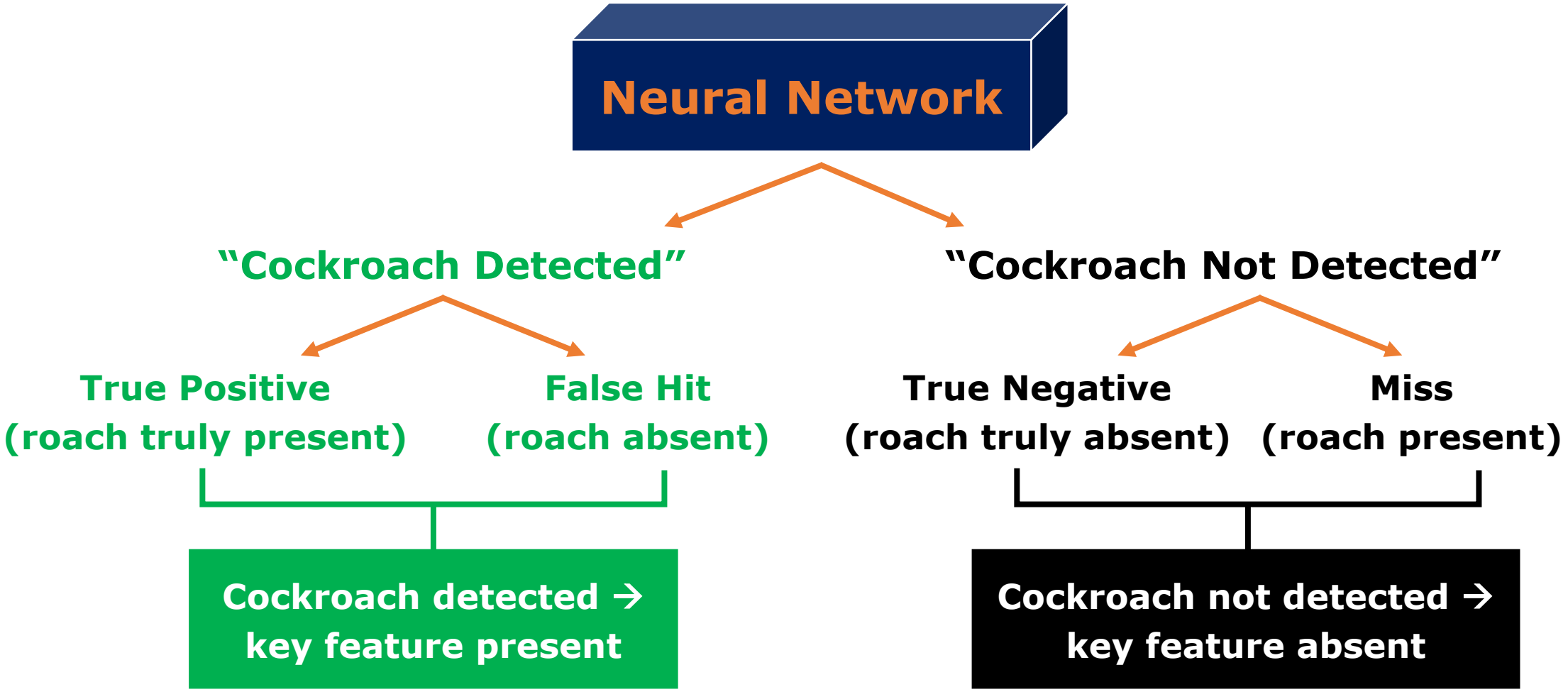
Validation Statistics:		
Metric	**Misses**	**False Hits**
96.0%	2 out of 115	1354 out of 21854

Metric: $1 - \frac{total\ misses}{total\ positives} - \frac{total\ false\ hits}{total\ negatives}$, **Miss** – missed roach image, **False Hit** – falsely detected roach image

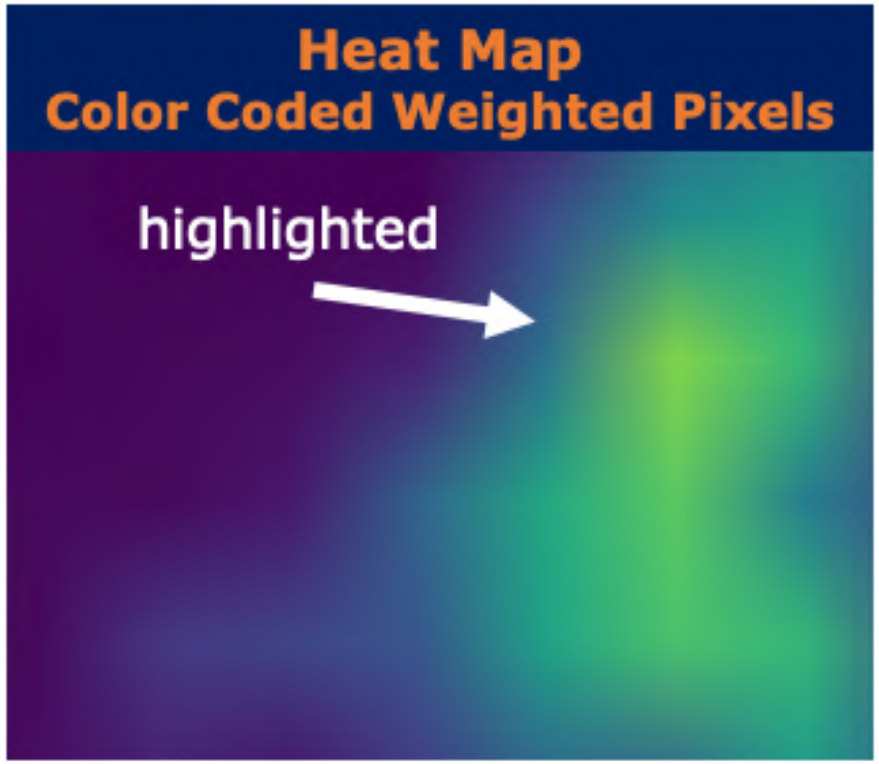
- Research question → to understand how NN detects cockroaches:

Do NNs detect key features visible to humans?

Logic for Identifying NN's Key Features



Procedure for Identifying NN's Key Features

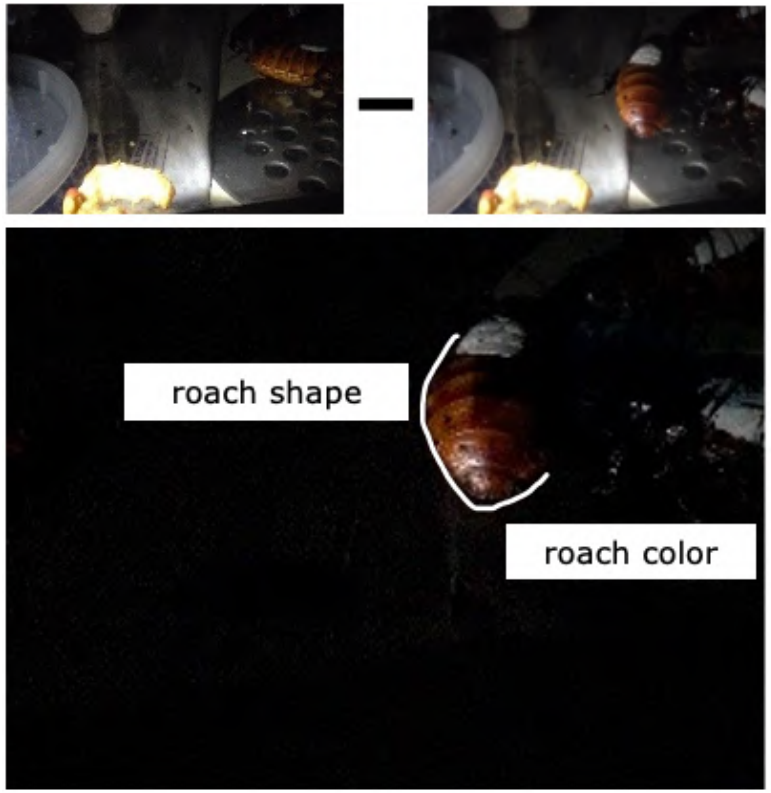


Key features → Large weighted pixel values → Brightly highlighted in heat map

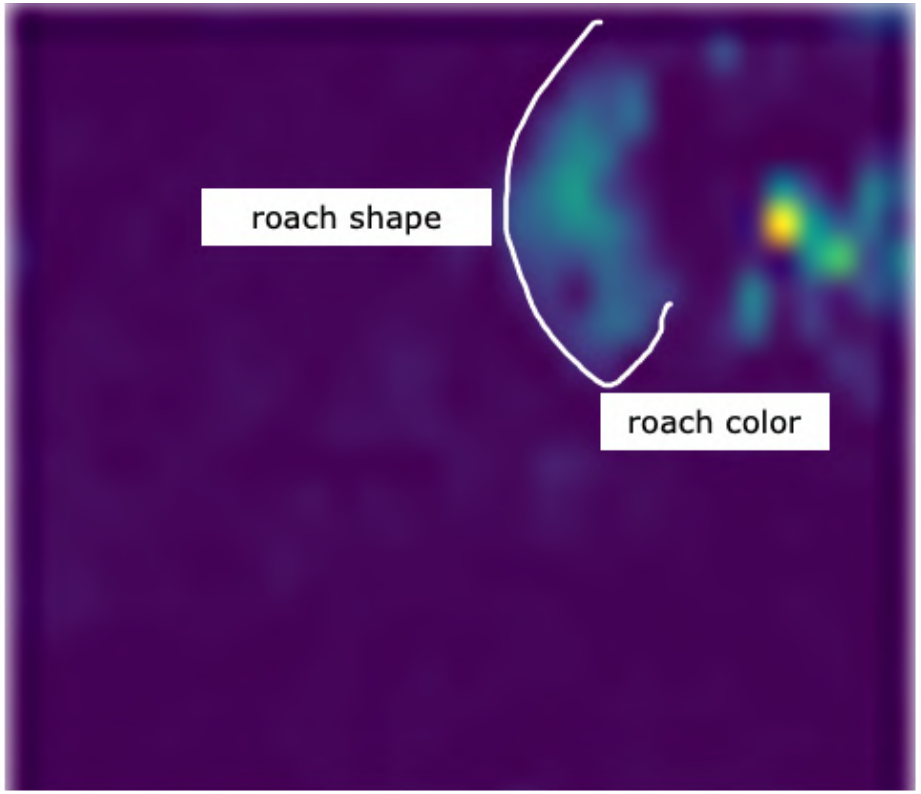
True Positive Results

Correctly Detected Cockroach

Subtracted Image



Heat Map



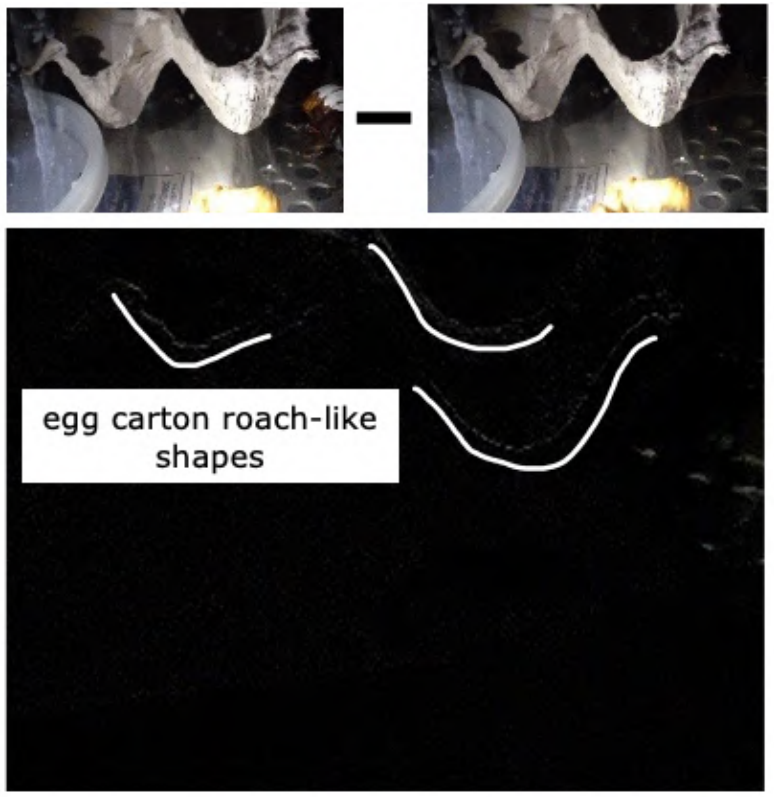
Input image has roach shape & color. Heat map highlights roach shape & color.

NN detects roach.

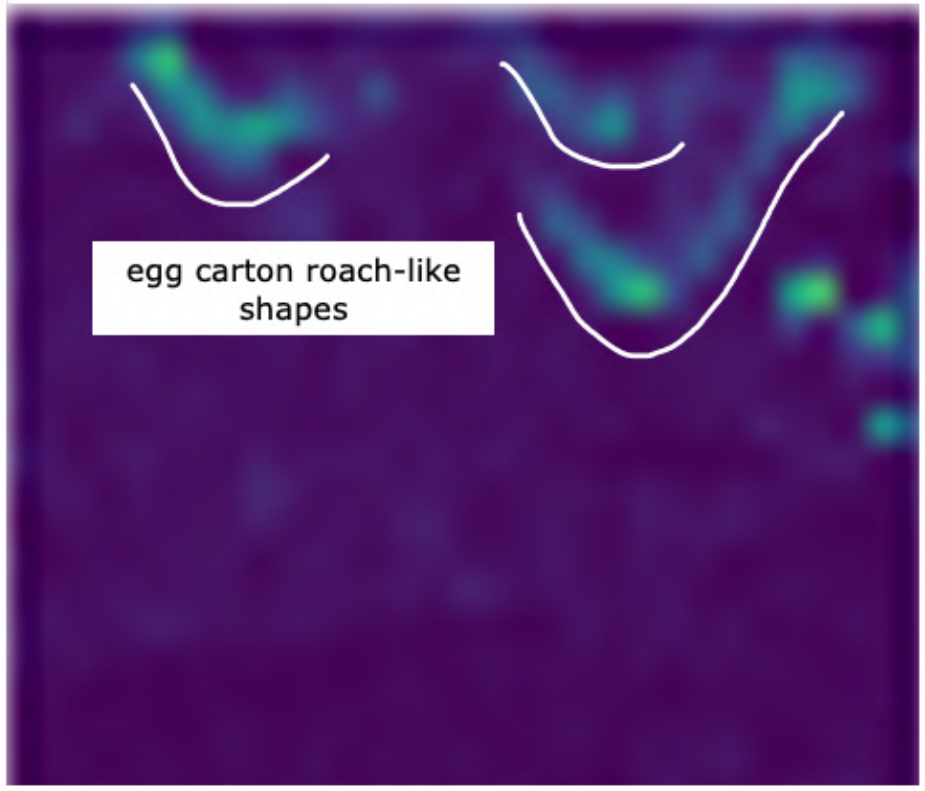
False Hit Results

Incorrectly Detected Cockroach

Subtracted Image



Heat Map



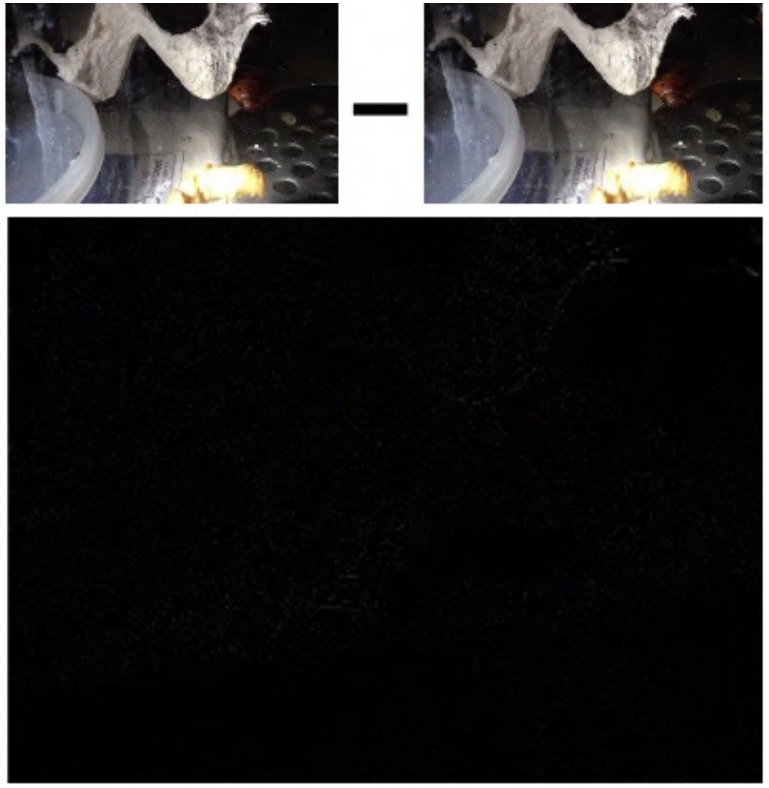
Egg carton creates roach-like shapes which the heat map highlights.

NN incorrectly mistakes egg carton for roach.

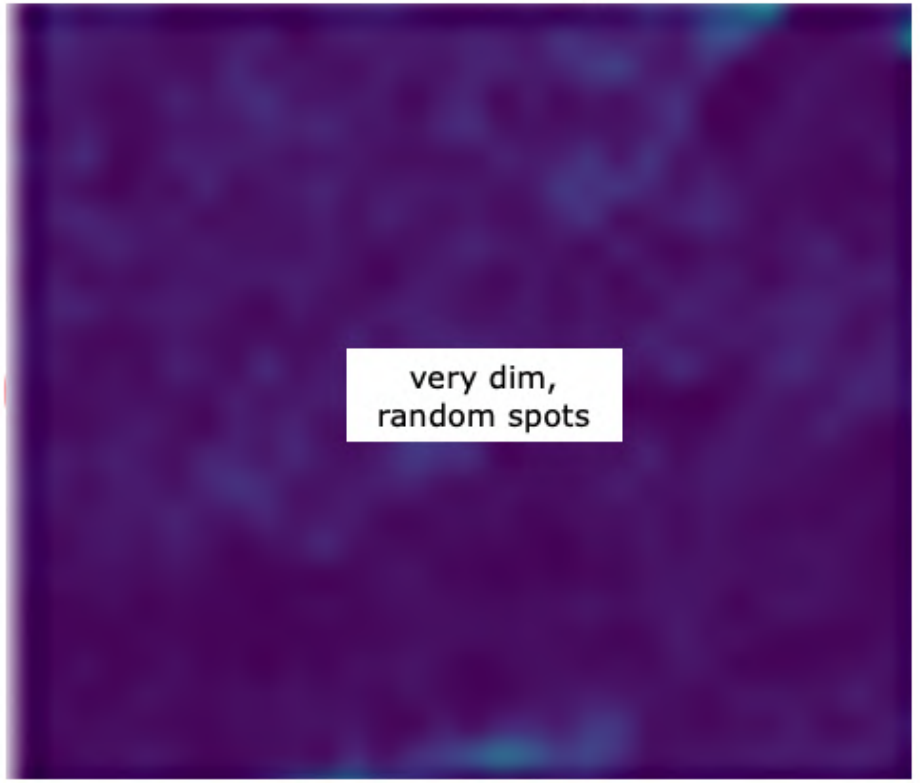
True Negative Results

Correctly Detected No Cockroaches

Subtracted Image



Heat Map



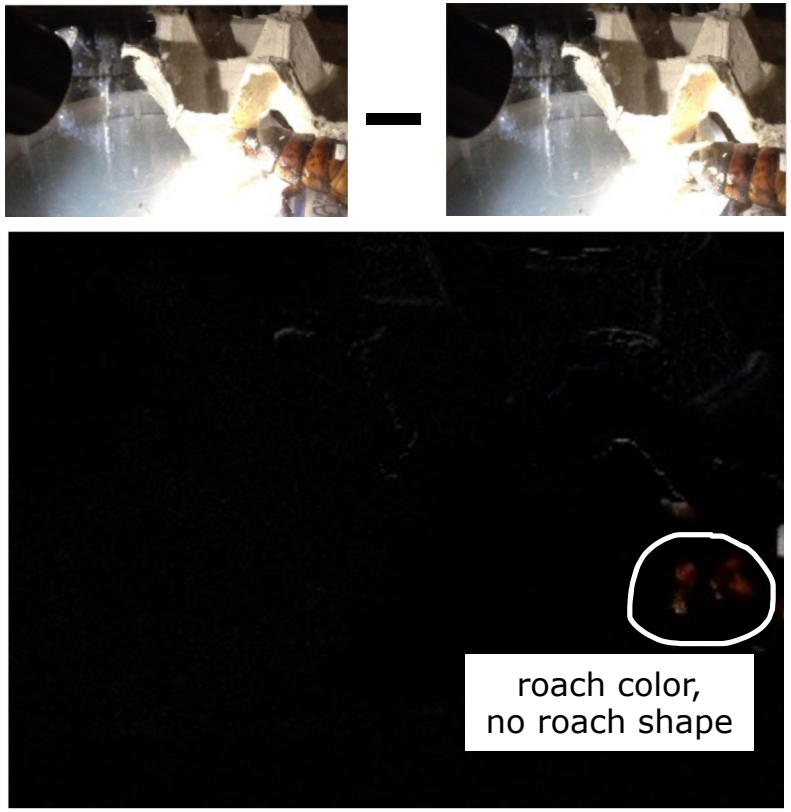
Input image looks pitch black. Heat map doesn't brightly highlight any features.

NN doesn't detect roach.

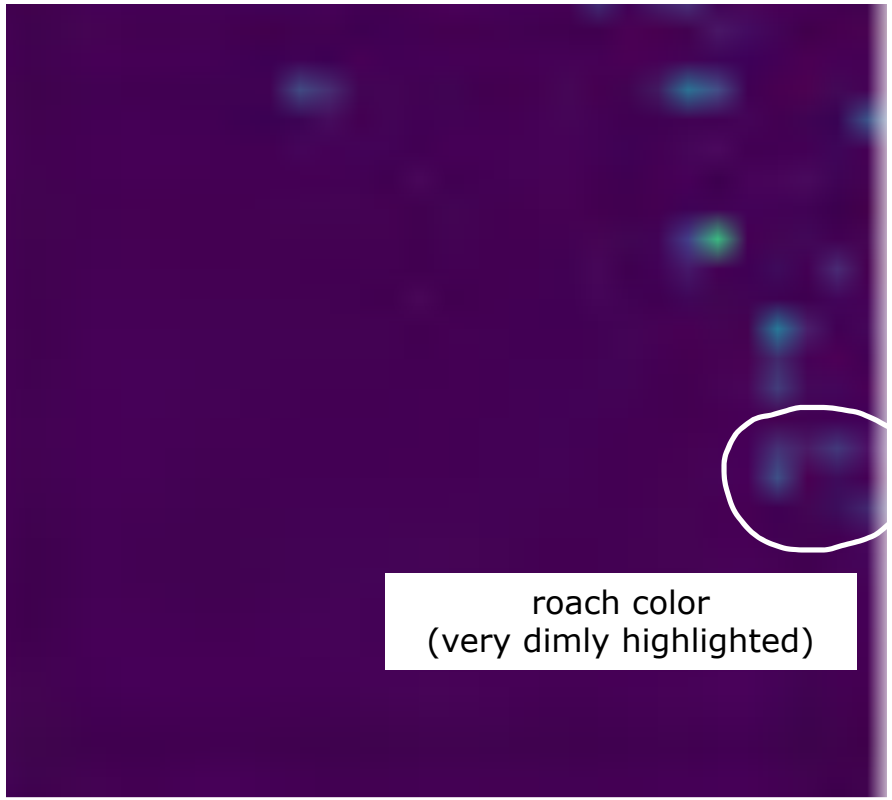
Miss Results

Incorrectly Detected No Cockroaches

Subtracted Image



Heat Map



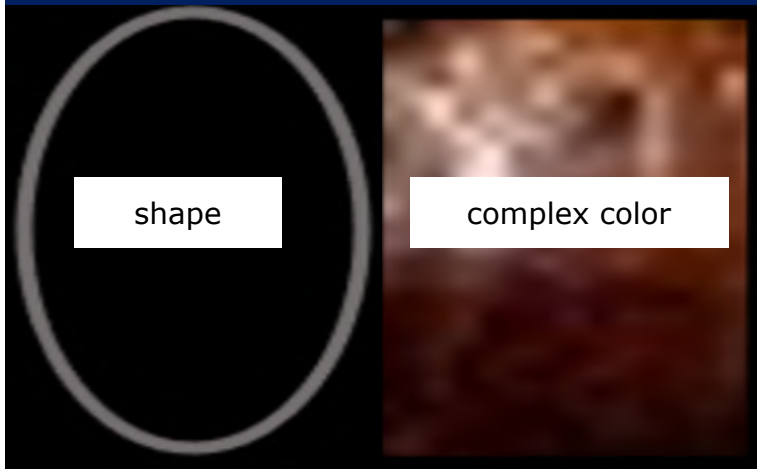
Input image has a little roach color, but no roach shape. Heat map highlights color dimly. **NN doesn't detect roach.**

Verification of Key Feature

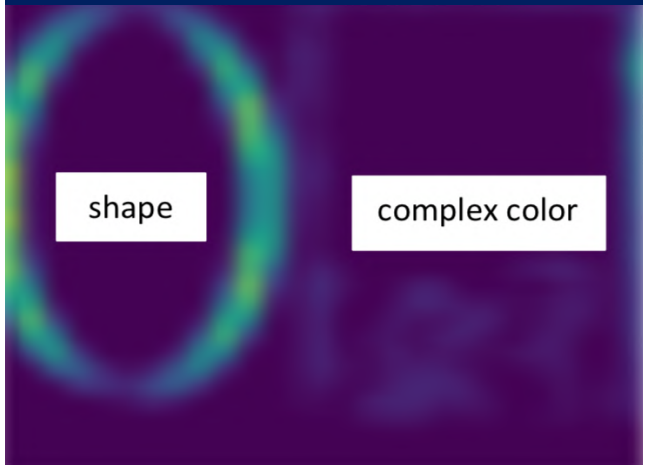
Cockroach Shape

- Results slides showed NN's key feature is roach shape
- To verify, I made 2 verification images with figures representing roach shape & color
- Inputting verification images into NN created heat maps

Verification Image



Heat Map



Oval highlighted brightly → roach shape is key feature.

Rectangle highlighted dimly → roach color isn't key feature.

NN vs. Optimizing Without Weights

- Wrote pixel threshold optimizing program without weights to detect cockroaches
- Program (without weights) worse than NN (with weights) → had more misses

	Optimizing Without Weights	Neural Network
Metric	68.2%	96.0%
Misses	72	2

- Misses had roach shape (NN key feature)

Weights are necessary for NN to learn key features.

Key features are important for effective object detection.

Conclusion and Future Work

- **NNs learn key features from training experience like humans**
  - This NN learned roach shape as key feature
- **Weighting pixel values → necessary for key features**
- **More weighting layers → more key features → more effective NN**
  - Less resources needed → more applications
    - Eg. self-driving cars, cancer & COVID-19 detection, facial recognition
- **More weighting layers → NN structure more similar to brain structure**
  - NN has 140 ”nodes”; Brain visual cortex has 140 million neurons

References

Link to GitHub with my neural network code & additional data:

https://github.com/olimu/Cockroach-NN.git

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