Predicting hatching dates for avian species using infrared cameras and machine learning models

TEXAS A&M UNIVERSITY
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Field Data Technologies

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USDA NRCS

HILL COUNTRY AVIARIES

Introduction and Background

Abstract

Artificial incubation is used in aviculture to rear rare birds in captivity. It is an important tool for rare bird conservation and can reduce the transmission of disease from parent to chick, stimulate re-nesting so birds can double reproductive output, and allow for medical support during hatching to maximize survival. Artificial incubation is imperfect and incubator settings are unknown for most bird species. As a result, eggs of many species are best left in the nest until just before hatching for the parent birds to provide the proper developmental conditions. In these scenarios, just before hatching, the eggs are brought in, the shells sanitized, and incubation and hatching are completed in an incubator. The problem is that egg-laying does not occur on a set schedule, requiring frequent nest box checks to track egg-laying, development, and hatching. Nest box checks can stress the nesting pair and cause reduced reproductive success. This paper proposes a method to replace nest box checks with a system to alert collections managers when hatching is imminent using machine vision from a camera mounted in the nest. Thermal imaging photos were taken of eggs (n=42) across multiple species of Psittaciformes and Anseriform. The air cell, visible on thermal imaging, was graded at a surface area of 0%, 10%, 20%, 30%, 40%, or 50% of the egg area on a 0-5 scale. A grade 5 air cell predicted imminent hatching 93% of the time. Air cell grades of 5 hatched significantly sooner than eggs in all other grades (t-test, $p < 0.001$). A machine learning model was able to detect grade 5 eggs 100% of the time. This method has great potential to monitor natural incubation and pull eggs for hand rearing before hatching.

Infrared photography and machine learning a veterinary tool for egg health

- Thick or opaque eggshells cannot be candled. Infrared egg viewers, such as the Emu Vision standalone candler (Emu Vision company, Minnedosa, Manitoba, Canada), are widely used, including at TAMU.
- Classification eggs using infrared photography has been studied in chickens.

Mehdizadeh, S. A., Minaei, S., Hancock, N. H., & Torshizi, M. A. K. (2014). An intelligent system for egg quality classification based on visible-infrared transmittance spectroscopy. Information Processing in Agriculture, 1(2), 105-114.

Ishikawa, D., Ishigaki, M., & Gowen, A. A. (2021). NIR imaging. In Near-Infrared Spectroscopy (pp. 517-551). Springer, Singapore.

- Bird egg embryo development, infrared photography, and machine analysis are combined. This combination produced automated health monitoring.

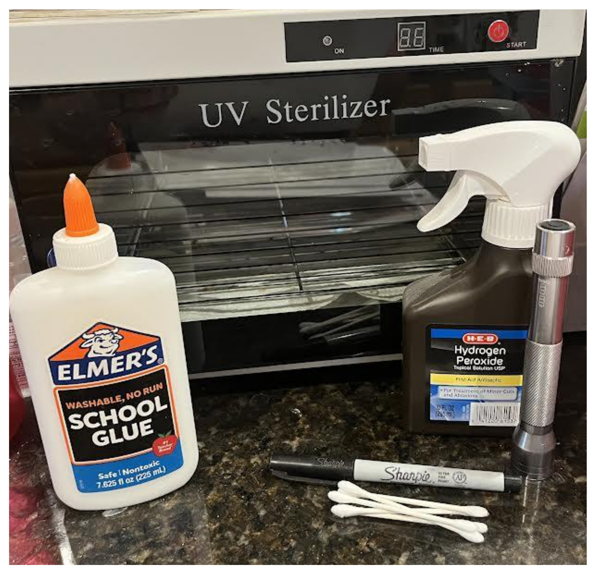
Zhang, M., & Wang, W. (2018, October). Detection of embryo eggs based on tensor depth calculation model. In 2018 International Conference on Image and Video Processing, and Artificial Intelligence (Vol. 10836, pp. 441-446). SPIE.

Lin, C. S., Yeh, P. T., Chen, D. C., Chiou, Y. C., & Lee, C. H. (2013). The identification and filtering of fertilized eggs with a thermal imaging system. Computers and Electronics in Agriculture, 91, 94-105.

Kwon, S., & Chen, C. H. (2013, May). Experimental model for determining developmental stage of chicken embryo using infrared images and artificial neural networks. In Thermosense: Thermal Infrared Applications XXXV (Vol. 8705, pp. 130-140). SPIE.

When eggs are collected from nests, they undergo a standardized sanitation protocol to limit disease transmission

- Eggs are carefully transported in padded bowls.
- Each egg is cleaned of large debris (i.e. feces).
- Hydrogen peroxide spray kills anaerobes and further remove debris.
- Eggs are placed in a UV sterilizer for 3 minutes
- Each egg is then candled and labeled.
- Notes are entered on cracks, fertility, shape, etc.
- Any eggs that are cracked are repaired if the membrane is still intact under the shell.
- Eggs are placed in the incubator based on size between the rollers.
- Bedding from egg transport and supplies used to perform sanitation are disposed of.



Objective

Infrared technology using a FLIR camera, and a machine learning model can be used to numerically grade the drawdown of an air cell with significant accuracy within 72 hours of external pipping and hatching.

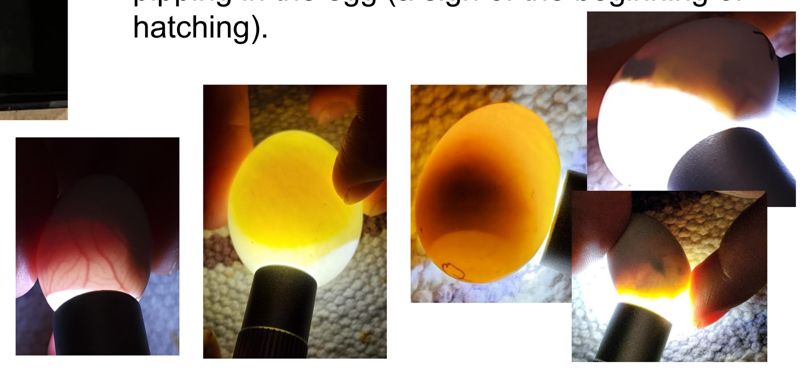
- Infrared cameras can be used to analyze an air cell in an egg
- A machine learning model and artificial intelligence can be trained to automatically grade the air cell size in an egg to predict when an egg is beginning to hatch
- The model can be applied to multiple species and be applied to conservation projects and the technology implemented in the field and monitored remotely

Methods

Daily candling and health checks were performed on each of the eggs

A flashlight was used to candle the eggs and perform a visual assessment of the embryo in the egg. The air cell was also inspected to monitor "draw down" and watch for internal pipping in the egg (a sign of the beginning of hatching).

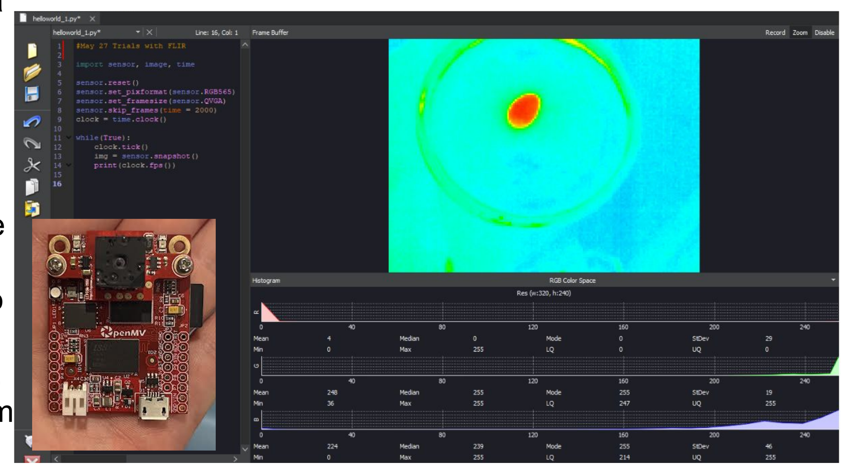
The Buddy egg monitor was used to monitor the heart rate and movement of the embryo in the egg. For eggs that were abnormal in appearance, or that were internally pipped, monitoring vitals was more important.



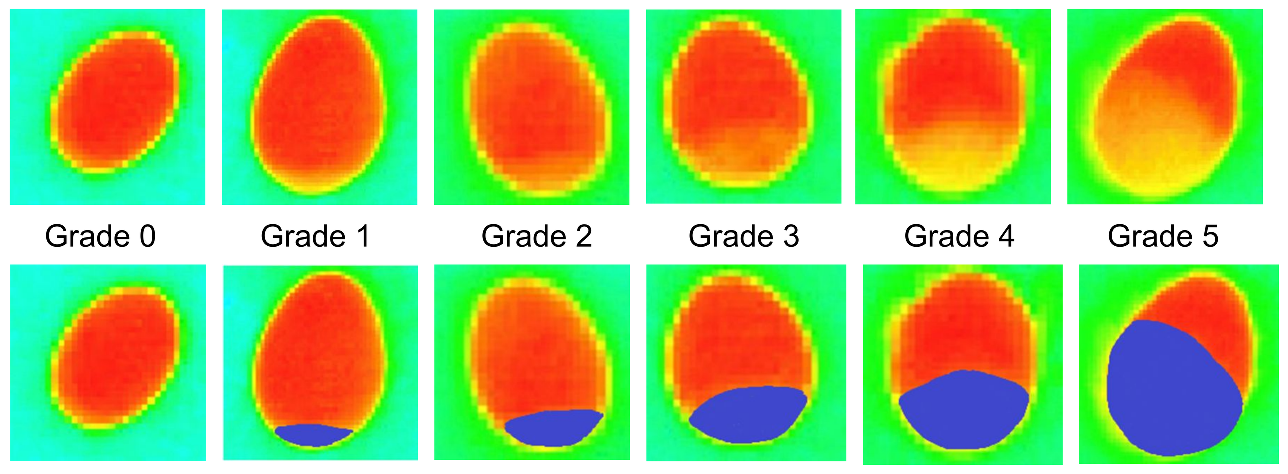
Normal | Infertile | Abnormal

A FLIR camera was used to obtain photographs of the eggs using script optimized in OpenMV IDE

- A 6-inch diameter bowl was used with a bedding depth of 1 inch for a photography station.
- The camera was placed 12 inches above the egg using a stand to prevent the camera from moving and to allow for replication
- Eggs were carefully pulled from the incubator individually.
- Smaller eggs were analyzed first to avoid visual confusion due to heat signatures left by the previous egg.
- Dynamic range of infrared spectrum was allowed to auto adjust to produce greater contrast between the embryo and the air cell



FLIR Images from OpenMV IDE Categorized from Grade 0 through Grade 5

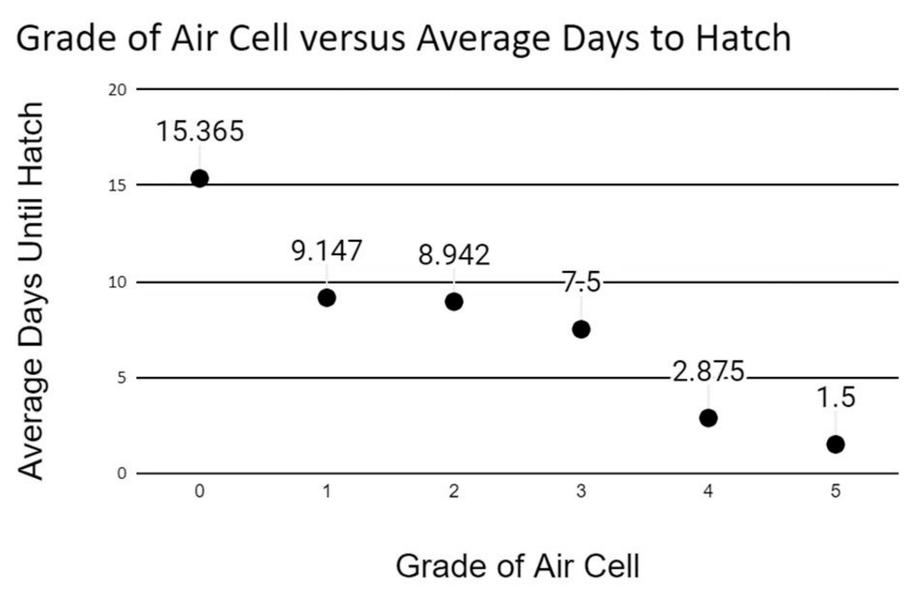


Grade 0 | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5

Blue shading is indicative of where the air cell is in the egg. Grading of the air cells is based on size increase of the air cell through the period of incubation.

Eggs from each photo collection were graded and aged from the day of hatch

- A 28 day incubation period was assumed.
- 137 eggs were utilized for photo collection.
- 15 species were followed to hatching.
- 42 individuals were monitored to hatching without complication.



Results and Conclusions

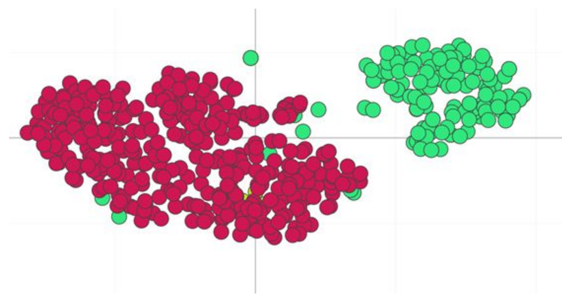
Machine learning model outcomes

Vertex AI Confusion Matrix

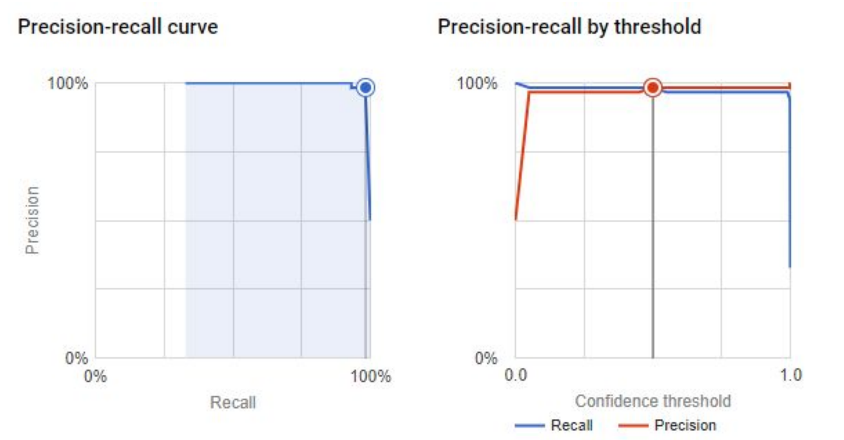
True Label/Predicted Label	Undeveloped Air Cell	Grade 5 Air Cell
Undeveloped Air Cell	98%	2%
Grade 5 Air Cell	0%	100%

Edge Impulse Cluster Analysis

- Grade 5 air cells were predicted and labeled true with 100% accuracy post training



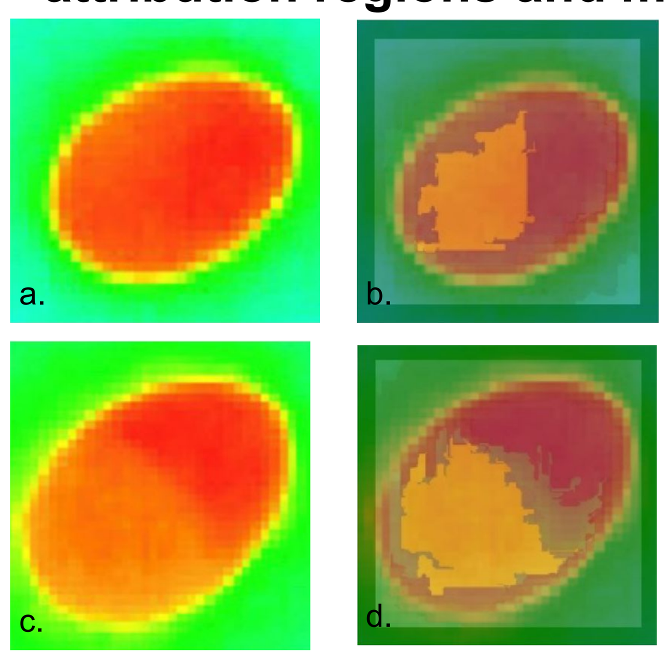
Precision-recall curve and precision-recall threshold were measured using Vertex AI



- Overall average precision: 0.998
- Precision: 98.3%
- Recall: 98.3%
- Total images: 583
- Training images: 466
- Validation images: 59
- Test images: 58

- No false negatives were produced during the validation and testing of the grade 5 air cell
- A single false positive image was labeled incorrectly according to the generated confusion matrix

XRAI is used to validate data and visualize attribution regions and map detection of the air cell



- XRAI is an "explainability" validation tool accessible in Vertex AI to allow for better understanding of the model's decision making in classifying images
- XRAI highlights the pixels that are most influential in decision making.
- The model appears to be correctly focusing on the air cell location and air cell size, indicating successful selection of training data and model type selection.

a. Egg with a grade 0 air cell (image only)
b. Egg with a grade 0 air cell with XRAI overlaid
c. Egg with a grade 5 air cell (image only)
d. Egg with a grade 5 air cell with XRAI overlaid

Conclusions

- For n=43 (across multiple species of Psittaciformes and Anseriform) air cells with a grade of 5, hatch occurred within 36 hours 93% of the time. The remaining 7% hatched within five days. This indicated grade 5 as good indicator of imminent hatching.
- A machine learning model produced by Google Vertex AI outperformed a similar model produced in the Edge Impulse software. The model detect grade 5 100% of the time, with no false negatives for n=58 test images.
- Further modifications can be made to the programming to alert researchers and collections managers of inappropriate air cell growth if the air cell enlarges too early in incubation, indicating shell break.
- Timely attention to hatching allows for medical intervention.

Funding: USDA Natural Resources Conservation Service: Conservation Innovation Grants.

Student Support: Boehringer Ingelheim VSP, Texas A&M School of Veterinary Medicine and Biomedical Sciences