An AI-based 3D Bat Movement Tracking System at Wind Energy Facilities using Multi-Thermal Video Cameras

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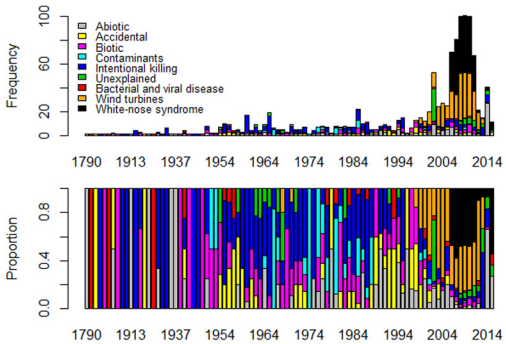
Motivation

Growing Concerns of Increased Bat Mortalities

Motivation for building this kind of tool comes from **the dead bats**. Bats are important for ecosystems, providing services like pest control and pollination. However, starting around 2000s, the global increase of industrial wind-power facilities contributed significantly in bat mortality causes.



O'Shea, T.J., Cryan, P.M., Hayman, D.T.S., Plowright, R.K. and Streicker, D.G. (2016), **Multiple mortality events in bats.** Mammal Review, 46: 175-190. https://doi.org/10.1111/mam.12064

Studies of bat behavior and interactions with turbines have occurred for nearly two decades and yet, **little is still known about their behavior and interactions with turbines** during their active period, limiting the research community's understanding of the risk. The capability to **closely monitor the real-time behavioral states** or **mere presence of bats flying in the rotor-swept airspaces around wind turbines** during nights is crucial. It facilitates expedited data retrieval, providing valuable insights to enhance our understanding of the factors driving risks to bats from wind energy.

Cost-effective Strategy to Monitor Bat Activities

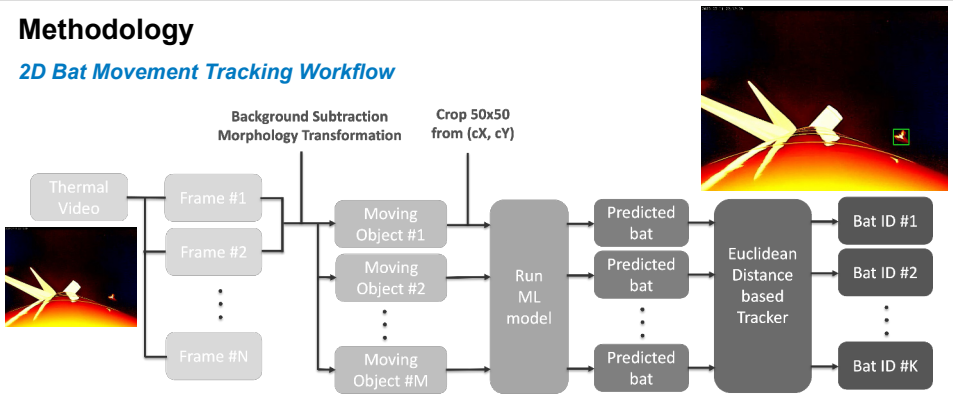
Characterizing patterns of behavior that increase the risk to bats at wind turbines while collecting real-time environmental conditions associated with such risk requires **consistent, long-term, easy-to-implement, and broadly scalable observation and monitoring methods**. Thermal-infrared imaging (hereafter 'thermal video cameras') record video of bats flying near wind turbines emerges as a promising technology for investigating bat behavior, offering continuous monitoring capabilities around wind turbines.

However, the sheer volume of data generated by continuously operating thermal-imaging systems surpasses **human capacities for manual review**. To leverage the potential of real-time thermal-imaging methodologies in quantifying nocturnal bat activities at wind turbines, we have pioneered **3D computer vision techniques within a deep learning framework**. This innovation enables the automatic detection and classification of bats, birds, and insects in thermal-imaging videos captured at wind turbine sites, facilitating efficient and accurate data analysis for enhanced understanding and mitigation of bat-wind turbine interactions.

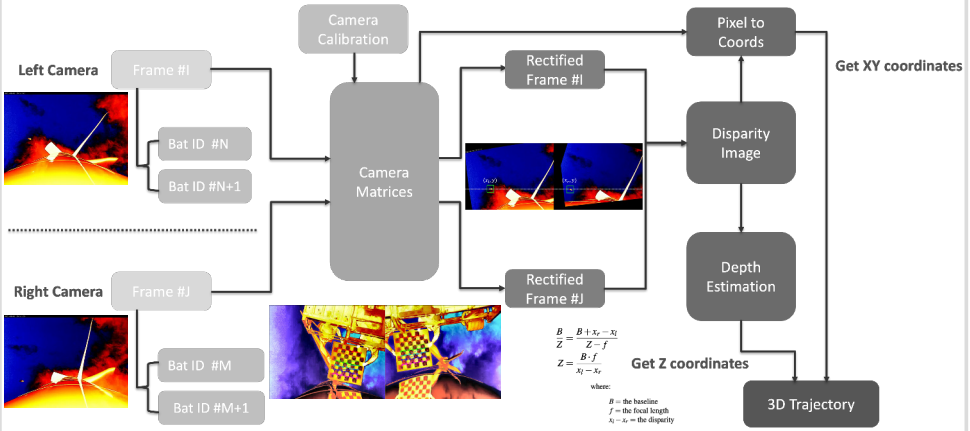
Three thermal cameras (AXIS Q1941-E Thermal Network Camera). Each sensor was mounted 70.25 inches off the ground/up the turbine and were 37.5 inches apart, pointing up at the blade. All recordings were collected with matching timestamps using a GPS module.

Methodology

2D Bat Movement Tracking Workflow

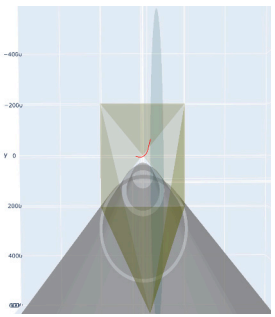


3D Bat Movement Tracking Workflow



Conclusion

- Moved the research community and industry closer to fully automated wildlife behavioral analysis and real time reporting to help expedite the research
- Built multiclassification model with the ability to distinguish between bats (93.2%) , birds (94.4%), insects (83.5%) and non-biological objects (99.1%)
- Cost effective thermal tracking system that
  1) is computationally inexpensive with the ability to run in real time on a personal computer
  2) can detect and classify animals moving in the field of view
  3) can provide the 3D flight trajectories
  4) can be easily retrained to enhance performance on other types of objects and applications
  5) is entirely open source, allowing it to be accessed, maintained, understood, adapted, and improved upon by a broad range of end users. (https://github.com/NREL/WEBAT)
- Future works
  - Expand the monitoring system to include other type of sensors
  - Bat behavioral studies
    - Understand the interaction of bats with wind turbines



Bat Detection

Experimental Set up

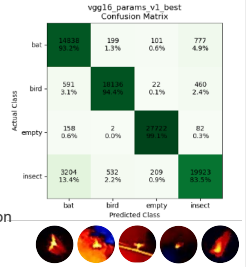
- GPU setting with Skynet from the Bioenergy Science Technology Directorate at NREL
- NVIDIA RTX3090 with Driver Version 470.57.0, CUDA, cuDNN, TensorFlow library

Dataset

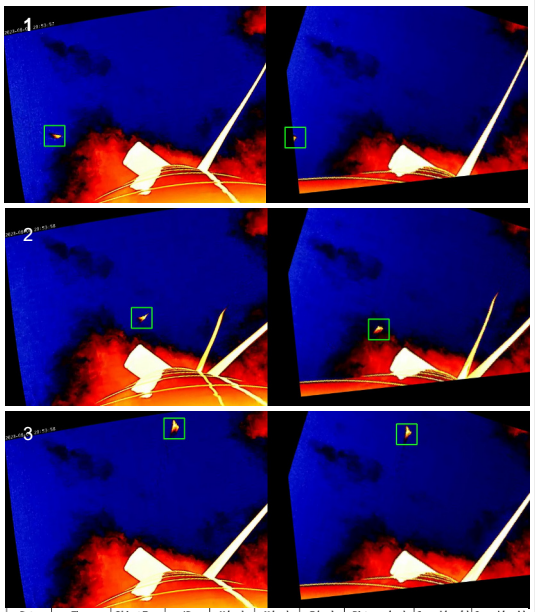
- **870,033 images** of unified 50x50 size
- 4 classes – bat, bird, insect, and non-biological object

Transfer Learning

- Backbone model option:
  - **VGG**, ResNet, Inception, Xception
- Hyperparameter choices:
  - # of freezing layers, # of classification layers with units, weight initialization, optimizer, learning rate, etc.
- Achieved **0.927124** for the averaged test accuracy :
  - bats(93.2%) , birds(94.4%), insects(83.5%), non-biological objects(99.1%)



3D Bat Movement Tracking Results



Date	Time	Object Type	ID	X (cm)	Y (cm)	Z (cm)	Distance (cm)	Speed (cm/s)	Speed (mph)
8/8/23	20:52:38.767	bat	282	-102.039	-136.199	3147.524			
8/8/23	20:52:38.800	bat	282	-85.3062	-134.804	3146.019	16.8578438	510.843752	11.4272493
8/8/23	20:52:38.867	bat	282	-60.9044	-127.832	3143.142	25.54073571	381.205011	8.52731323
8/8/23	20:52:38.900	bat	282	-49.0522	-129.227	3139.079	12.6069129	382.027664	8.54571546
8/8/23	20:52:38.967	bat	282	-22.5589	-127.832	3133.988	27.01396465	403.193502	9.01918178
8/8/23	20:52:39.000	bat	282	-14.8898	-132.713	3127.92	10.92925229	331.189463	7.4084973
8/8/23	20:52:39.034	bat	282	-3.73471	-133.41	3120.779	13.26325241	390.095659	8.72619137
8/8/23	20:52:39.200	bat	282	38.0968	-162.692	3112.309	51.75971537	311.805514	6.97489071

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy's Wind Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

15th Wind Wildlife Research Meeting
Corpus Christi, TX
November 12 – 15, 2024
NREL/PO-5000-92659