Novel Approach to Autonomous Mosquito Habitat Detection using Satellite Imagery and Convolutional Neural Networks for Disease Risk Mapping

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November 23, 2022

Abstract

Mosquitoes are known vectors for disease transmission that cause over one million deaths globally each year. The majority of natural mosquito habitats are areas containing standing water such as ponds, lakes, and marshes. These habitats are challenging to detect using conventional ground-based technology on a macro scale. Contemporary approaches, such as drones, UAVs, and other aerial imaging technology are costly when implemented. Multispectral imaging technology such as Lidar is most accurate on a finer spatial scale whereas the proposed convolutional neural network(CNN) approach can be applied for disease risk mapping and further guide preventative efforts on a more global scale. By assessing the performance of autonomous mosquito habitat detection technology, the transmission of mosquito borne diseases can be prevented in a cost-effective manner. This approach aims to identify the spatiotemporal distribution of mosquito habitats in extensive areas that are difficult to survey using ground-based technology by employing computer vision on satellite imagery. The research presents an evaluation and the results of 3 different CNN models to determine their accuracy of predicting large-scale mosquito habitats. For this approach, a dataset was constructed utilizing Google Earth satellite imagery containing a variety of geographical features in residential neighborhoods as well as cities across the world. Larger land cover variables such as ponds/lakes, inlets, and rivers were utilized to classify mosquito habitats while minute sites such as puddles, footprints, and additional human-produced mosquito habitats were omitted for higher accuracy on a larger scale. Using the dataset, multiple CNN networks were trained and evaluated for accuracy of habitat prediction. Utilizing a CNN-based approach on readily available satellite imagery is cost-effective and scalable, unlike most aerial imaging technology. Testing revealed that YOLOv4 obtained greater accuracy in mosquito habitat detection than YOLOR or YOLOv5 for identifying large-scale mosquito habitats. YOLOv4 is found to be a viable method for global mosquito habitat detection and surveillance.

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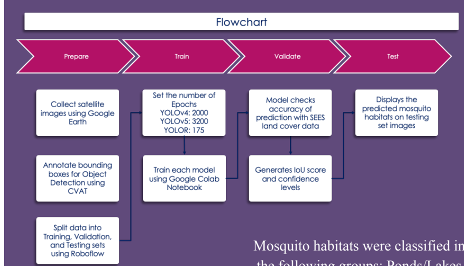
Introduction

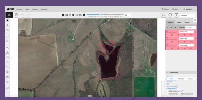
Mosquito-borne vector diseases cause over 1 million deaths each year, the preponderance of which occur in underdeveloped nations with poor medical infrastructure. Modern approaches(Drones & UAVs) to map mosquito-spread in the form of habitats are extremely costly, leaving these nations even more vulnerable to deadly diseases. Data derived from multispectral imaging technology from satellites additionally takes time to further interpret and analyze, contributing to a slow response to a possible epidemic in a region.

Due to these approaches being the only method of mosquito habitat identification, there are no current efficient methods available. As a result, we propose and utilize the approach of artificial intelligent convolutional neural networks, where through readily available satellite imagery, we train the AI network to identify where mosquito habitats are when given a satellite image. Due to the AI being able to predict photos within milliseconds, vast areas can be mapped quickly and efficiently, enabling scientists and governments to track possible paths and areas for mosquito spread and control epidemics at a more efficient and cost-effective pace than before.

Methodology

Our study analyzed the results of mosquito habitat prediction data of 3 different CNN models (YOLOv4, YOLOv5, YOLOR). There are 4 steps involved in this process: Prepare, Train, Validate, and Test.





Mosquito habitats were classified in the following groups: Ponds/Lakes, River Inlets, Rivers. The annotated dataset of about 500 images was divided into a 62-16-25 % Train/Test split ratio using Roboflow. The images were exported using each model's respective frameworks (YOLOv4 - Darknet, YOLOv5 & YOLOR - TensorFlow)

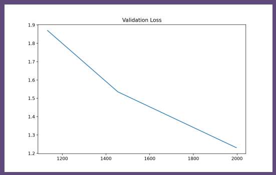
The satellite output data was then analyzed for accuracy of mosquito habitat detection and compared with ground truth annotations.

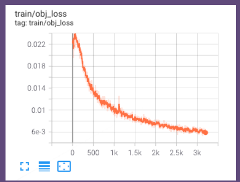
Training

The graphs below depict the average objective loss for all 3 tested models during training. The lower the loss, the greater the accuracy.

YOLOR

YOLOv4





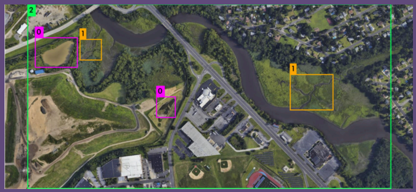
YOLOv5

Results

Through analysis and experimentation utilizing the different convolutional networks and the corresponding frameworks, it was found that YOLOv4 performed with extreme accuracy and precision, identifying most mosquito habitats with extreme speed.

Ground Truth Annotation

YOLOv4

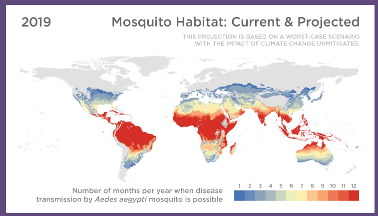


YOLOv5

YOLOR

Conclusion

Compared to other Aerial approaches for mosquito habitat detection, CNNs are the quickest, most efficient, and cost effective way to go. YOLOv4 performed with the highest accuracy among the 3 models with an average IoU score of 55.85%. The proposed solution can be implemented on a global scale using readily available satellite data. It can be used to aid in preventative measures of the global transmission of mosquito-borne vector diseases through risk mapping as well as integrated in public health policies. The spatiotemporal distribution of mosquito habitats can additionally serve to map impoverished and hard to reach areas in order to determine mosquito migration patterns. Hotspots can be linked with the effects of climate change and variables such as soil moisture, temperature, and land use. There are a multitude of uses for mosquito habitat distribution data, and CNNs are a cost-effective, autonomous approach to achieving this.



<u>Limitations</u>

Micro scale habitat data like smaller sites such as puddles, footprints, and tires tend to go unnoticed by this model as its scope is geared towards dealing with larger bodies of standing water. It also does not take into account nearby vegetation and weather-related data that may have an impact on breeding patterns and female oviposition. Future research could include an integration of such factors mentioned above to narrow the amount of viable mosquito habitats.

<u>Acknowledgements</u>

Thank you to the Earth Systems Explorers/Mosquito Mappers mentors (Rusty Low, Peder Nelson, Cassie Soeffing) and peer mentors (Pratham Babaria, Matteo Kimura, Faguni Gupta, Kavita Kar)

<u>Bibliography</u>

YOLOv4 (Alexey Bochkovskiy *et al*)

YOLOR (Chien-Yao Wang *et al*)

YOLOv5 (Glenn)