Control of Mosquito-borne Diseases Using Semantic Segmentation and Georeferencing of Aerial Images to Locate Breeding Sites

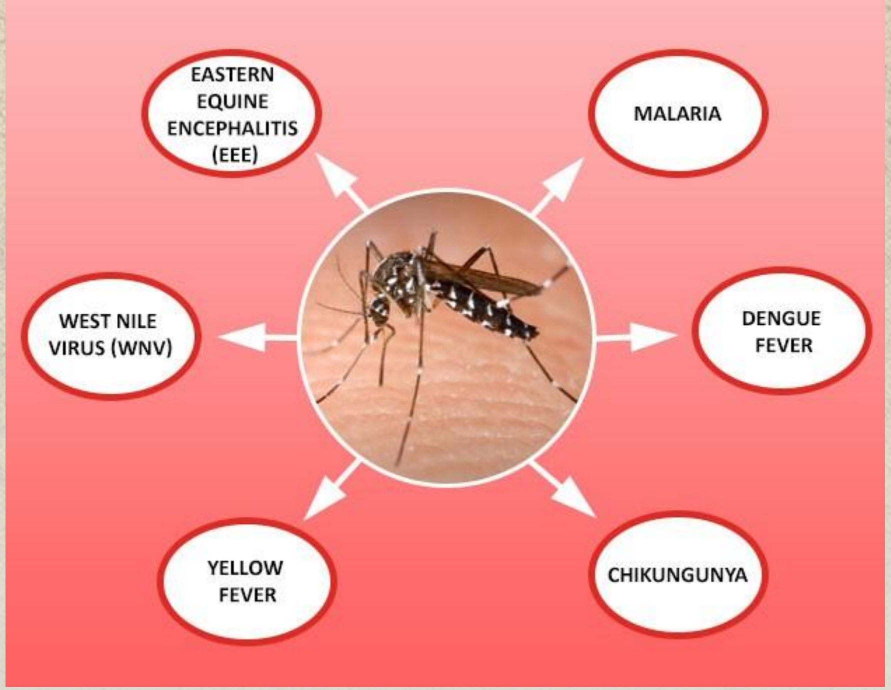
BHAVANI VENKATESAN

PROBLEM STATEMENT

Mosquito-borne diseases affect many millions of people in India every year

In monsoon season, mosquito breeding grounds (stagnant water) can appear and shift quite rapidly

Need an **automated way to quickly identify and treat potential breeding grounds** – manual methods are dependent on volunteers and cannot cover all areas quickly enough



Source: MediConnect India

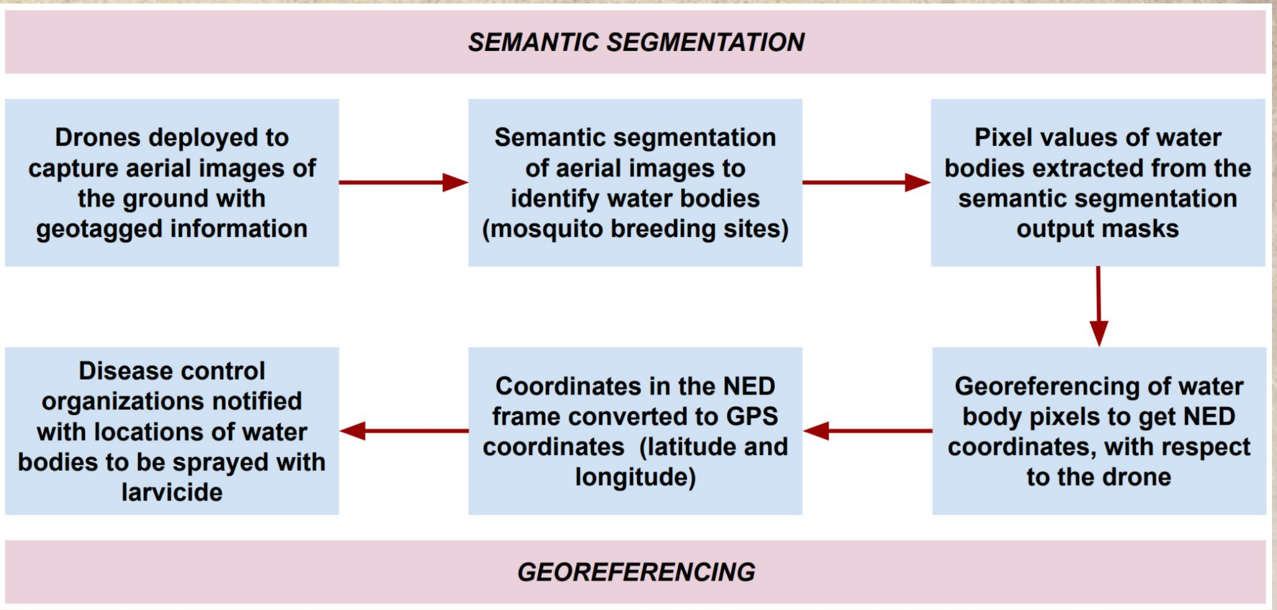
INNOVATION AND METHOD: USING DRONE IMAGES & MACHINE LEARNING

Employ drones fitted with cameras to take **high-resolution aerial images** of affected areas.

Automatically identify image pixels corresponding to water bodies using **<u>semantic segmentation.</u>**

Map these pixels to the coordinates of their ground locations using **<u>georeferencing techniques</u>** (must know drone position and orientation at moment of capture, and some camera & sensor parameters).

<u>More futuristic:</u> Could also use drones to spray larvicide in the identified breeding sites.

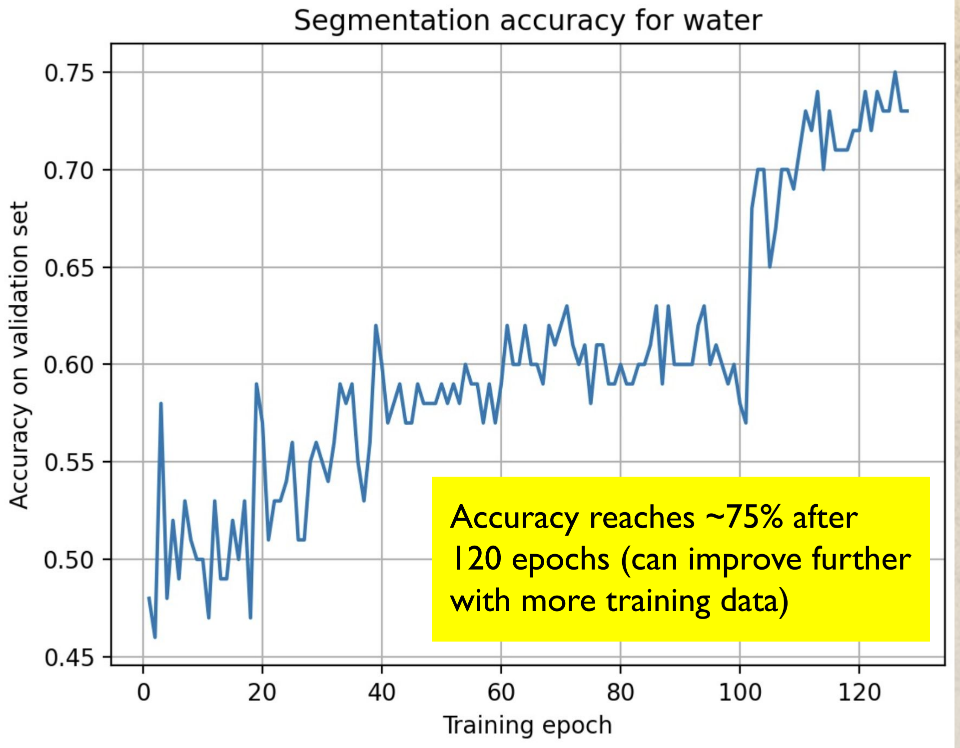


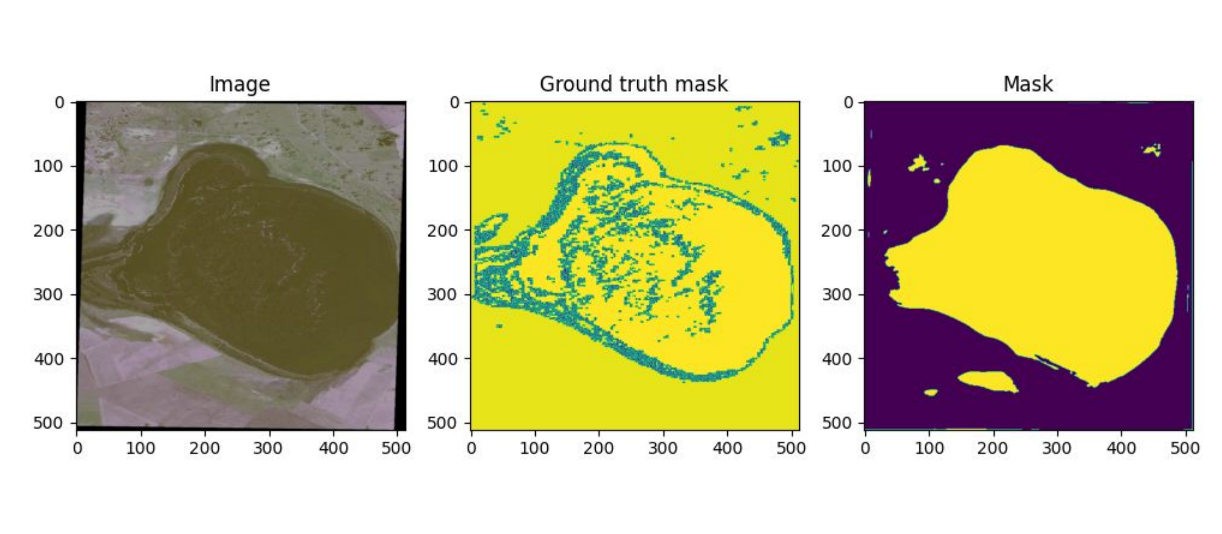
SEMANTIC SEGMENTATION

I developed a machine learning model (in PyTorch) for semantic segmentation of drone images, as part of the Science Internship Program (SIP) at Univ. of California, Santa Cruz (Summer of 2022).

Over the last few months, I improved this model to better detect water bodies by training it on more labeled images I found on Kaggle.

SEGMENTATION ACCURACY FOR WATER





Predicted water pixels (right) match image (left) quite well in this example

THE PROCESS OF GEOREFERENCING

The process of direct georeferencing involves transformations between five reference frames. A reference frame is an abstract coordinate system whose origin, orientation, and scale are specified by a set of reference points. In this case, the reference points are defined by different parts of the drone and its camera. The first transformation is from the image frame, which is the plane where the image is formed, to the camera frame, which is the plane at the point where the camera's aperture is. This is then transformed to the gimbal frame, and then to the drone's frame (center of gravity of the drone). Finally, this is transformed to the fixed North East Down (NED) coordinate system, whose origin can be chosen arbitrarily.

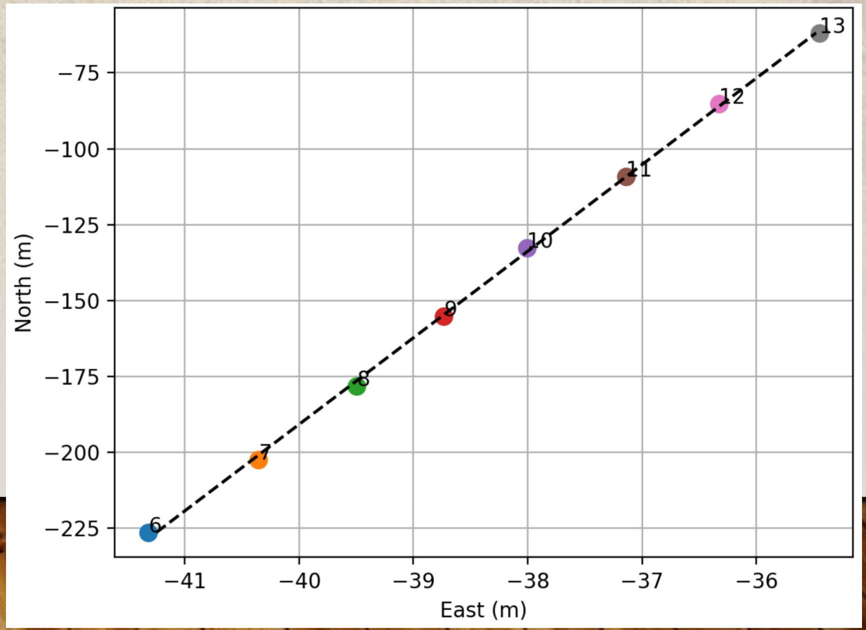
In this process, each transformation involves a three-dimensional rotation and translation. The rotations can be represented in the form of a rotation matrix by decomposing each rotation into three Euler angles representing the rotations about the x, y, and z axes. These rotations are the roll, pitch, and yaw respectively. The final rotation matrix representing the transformation from the image frame to the NED frame is derived by composing the rotation matrices for all the previous transformations. It is assumed that the height of the drone (Z_{NED}) is known, as the equations for X_{NED} and Y_{NED} are derived in terms of Z_{NED}.

PYTHON PROGRAM FOR GEOREFERENCING - FINDING THE YAW

The drone's orientation is defined by three angles, which are required for the georeferencing calculations. Since the drone's exact orientation is not known, the pitch and roll are assumed to be 0°, meaning that the drone is flying horizontally without any tilt. However, the yaw had to be calculated, as this is required to know which direction the drone is flying. In the dataset shared by Urban Matrix, all images are geotagged, so the latitude and longitude of the drone at the point of image capture is known for each image. The *pymap3d* library was used to convert these GPS coordinates to NED coordinates. Eight consecutive images were then chosen, and the NED coordinates of the drone at each of these points were plotted, taking the position of the drone in the first image as the origin. The yaw angle was estimated by first fitting a least-squares linear regression line to the drone's trajectory in the North-East plane, and then computing the inverse tangent of the slope of this line. **This gave a yaw of 0.03504029 radians.**

The estimated yaw value was compared with the value obtained by sweeping over 3600 hypothesized yaw values (in 0.1 degree steps) and finding the one resulting in the least sum of pairwise distances between the computed NED coordinates of a fixed object in images #6-10. **This gave a yaw value of 0.0837758 radians.**

Image Number	Latitude (deg)	Longitude (deg)	North (m)	East (m)
1	12.8115085	77.6472203	0	0
6	12.8094609	77.6468397	-226.5279644	-41.3213470
7	12.8096771	77.6468486	-202.6095496	-40.3550488
8	12.8098965	77.6468565	-178.3371151	-39.4973206
9	12.8101060	77.6468635	-155.1599266	-38.7373071
10	12.8103091	77.6468702	-132.6907761	-38.0098665
11	12.8105207	77.6468782	-109.2812620	-37.1412867
12	12.8107395	77.6468857	-85.07520431	-36.3269916
13	12.8109495	77.6468938	-61.84269898	-35.4475581



TESTING THE GEOREFERENCING PROGRAM

Once the yaw value is found using the method on the previous slide, the drone parameters and the coordinates of a point on the image can substituted into the equations for the *x* and *y* coordinates in the NED (ground) frame.

To show that the georeferencing program gives accurate results, five consecutive images taken from a moving drone (from the dataset shared by UrbanMatrix) were used for testing. A blue object that was present in all the images was used as the target point, and the georeferencing program was run on these five images to check if it gave the same latitude and longitude for the blue object when the drone is at different positions. For the georeferencing program, the calculated position of the target (the blue object) is very similar across all five images, showing high accuracy and consistency.

ACKNOWLEDGMENTS

- Dr. GVS Murthy from Indian Institute of Public Health Hyderabad for arranging Project NoFever for dengue control, which inspired this idea
- Divyanshu Pundir from UrbanMatrix for providing the geotagged aerial images
- Mentor at SIP for teaching me about semantic segmentation for vision-and-language navigation of drones
- Correia et al., “Comprehensive Direct Georeferencing of Aerial Images for Unmanned Aerial Systems Applications,” 2022 [for georeferencing]