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CS 445
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Final Project: Flight Trajectory Tracking

Motivation and impact: Why did you choose this topic? / What is the more general importance or impact?

I chose this project because I am passionate about aerospace technology and am interested in working in control systems or perception software in this industry. There are many use cases for flying object identification and tracking, specifically in the defense sector in the realm of drone/UAV detection. Camera sensing for approaching flying objects can be superior to other methods like radar for its low energy and high information quality when paired with ML. I was aiming to include some sort of machine learning aspect to this trajectory visualizing software since I have seen many examples of neural networks used for drone detection.

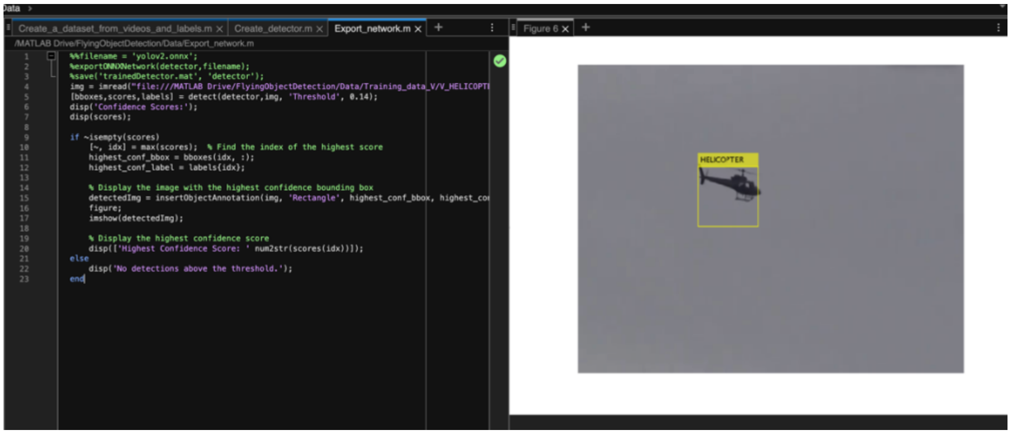
Approach: Describe how to achieve your results.

Firstly, I identified an acceptable dataset of flying object videos with accompanying ground truth bounding boxes online. This consisted of labeled tracking videos of drones, airplanes, helicopters, and birds for use in classification algorithms. After preprocessing the data, I create a darknet19 network for use in a YOLOV2 object detector, which is thoroughly trained on the dataset. The YOLOV2 detector is tested and refined over multiple trials, and then exported via ONXX format to be used in a python script. Given a video of a static-camera panoramic tracking of an object, we first sample certain key frames and form a homographic panorama. Splitting the panorama into sections, we then use the exported network to identify flying objects in the frame. The coordinates of the bounding box are used to form a trajectory of moving object over frames. Using the combined coordinates and some other logic, the trajectory field is displayed on the background, along with the classification result.

Results: Explain your results and their significance

My detector reaches a minimum of 1.95 Mini-Batch RMSE and 3.9 Mini-Batch Loss, which are very good indicators that the object detector is performing relatively well to identify items in the training dataset. When extrapolating this performance to a full tracking video of a helicopter, all but one frames were identified correctly spatially, which resulted in a highly accurate representation of the helicopter's flight path through the sky.

Neural Network

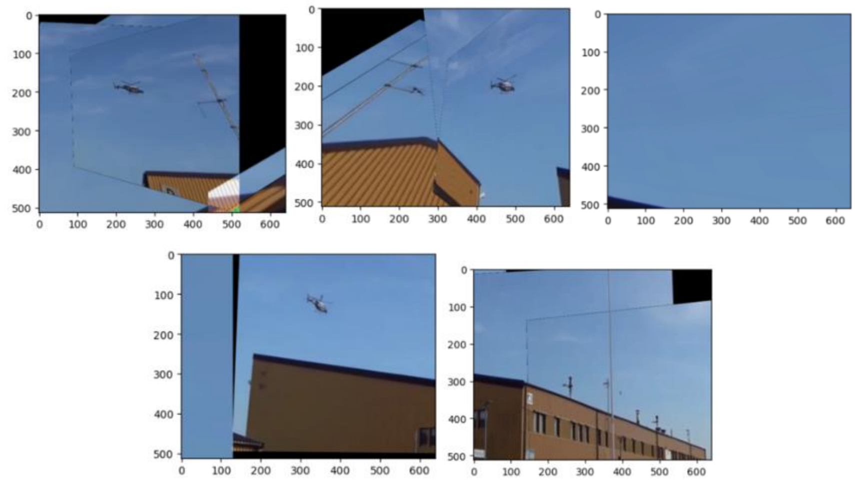


Object Detection Output: Positive Classification, Positive Detection

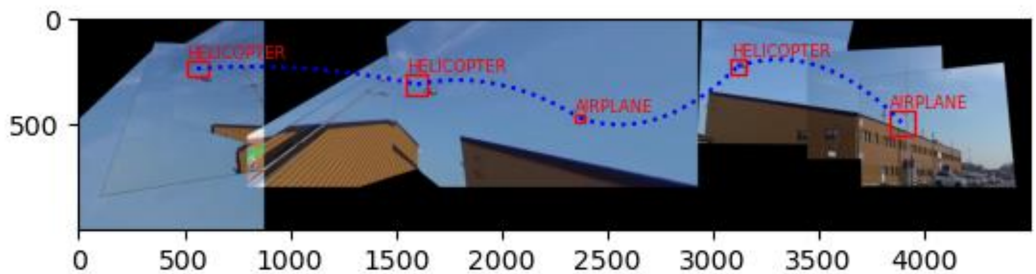
Object Detection Output: (Left)Positive Classification, False Detection [Second-highest Score]
(Right) False Classification, Positive Detection [Bird vs. Airplane]

Tracking:

Homographic Background panorama



5 Spliced Frames from Panorama used for Object Detection



Final Result: Flying Object Tracking

In all the five frames except the third, a bounding box is placed over the flying object correctly. Due to the distances involved and limitations of the dataset, for two selected frames, the object is identified as an airplane instead of a helicopter.

Implementation details:

I utilized a preexisting GitHub repository for the dataset of flying object videos and accompanying .mat files which had labels per frame. I organized all the YOLOV2 detector training work in MATLAB because there are many helpful preexisting functions and packages that make network design straightforward. The Computer Vision Toolbox and accompanying network features of darknet19 and mobilenetV2 came in handy for trying out different hyperparameters for the detector. Additionally, for the homography functionality I utilized my written code for project 5 of this course. Much adaptation was required for the homographies to work due to the steep angles.

• **Challenge / innovation:** Describe what you think was challenging or innovative about your project. Explain the effort required to interpret unclear steps to a paper's implementation or get a proposed new idea to work.

This project concerned many complex topics that weren't thoroughly covered in class, and that I wasn't initially familiar with. Much research and testing went into learning about activation layer functions like ReLU, SoftMax, Sigmoid, Leaky, and Binary Step. Attempting to optimize the training options also took several hours of experimentation. It also must be taken into consideration that the entirety of the project's research and implementation was conducted by one person. For these reasons, I believe I deserve 20 points for the challenge/innovation component of grading.

Acknowledgments:
UAV detection:
"Svanstrom F. (2020). Drone Detection and Classification using Machine Learning and Sensor Fusion".

Link to dataset:
https://github.com/DroneDetectionThesis/Drone-detection-dataset

Extensive use of MATLAB documentation:
https://www.mathworks.com/help/index.html?s_tid=CRUX_lftnav

YOLOV2 guidance
https://pyimagesearch.com/2022/04/18/a-better-faster-and-stronger-object-detector-yolov2/

Neural Network/Transfer function guidance
http://saedsayad.com/artificial_neural_network.htm#:~:text=The%20transfer%20function%20translates%20the,%2C%20piecewise%20linear%2C%20and%20Gaussian.&text=The%20output%20is%20set%20at,less%20than%20some%20threshold%20value.