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TEMPORAL FREQUENCY ANALYSIS (TFA): TARGET ISOLATION & SIGNAL OPTIMIZATION

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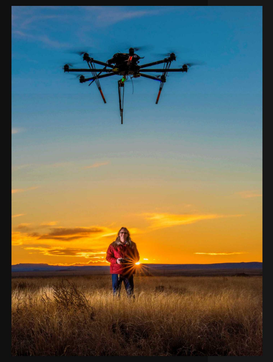
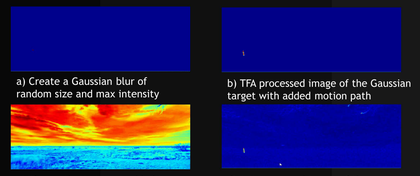
Introduction

Commercial CUAS solutions are agreeable due to their development level and availability. However, few systems possess a reliable method of UAS assessment. The challenges in imaging these small targets are many, which has resulted in a move away from them. However, this phenomenology can still be useful by combining the spatial and temporal information using frequencies. Valuable frequency content of an image can be obtained by monitoring the changing values of a pixel over time and the frequency content extracted and filtered. This approach allows us to view these small targets when we classically could not.



TFA Coefficient Optimization

The TFA process requires filtering of the frequency data for each camera pixel. In this work we view the filter as an optimizable problem to maximize contrast. This optimization requires knowledge of the ground truth state; a challenge with dynamic, quickly moving UAS with several variables that impact target contrast (sun, material, weather, etc.). To provide this truth data, a synthetic data generation process was utilized.



a) Create a Gaussian blur of random size and max intensity

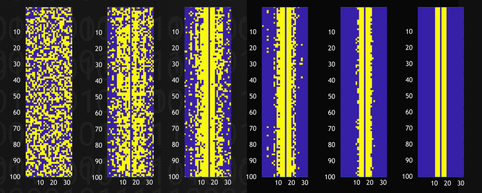
b) TFA processed image of the Gaussian target with added motion path

c) The synthetic target added to an image containing the background environment

d) TFA processed image of the background plus synthetic target data

SYNTHETIC DATA GENERATION OUTPUT SHOWS THE OUTPUT OF SYNTHETICALLY GENERATED DATA.

PROGRESSION OF OPTIMIZED FILTERS FROM THE GENETIC ALGORITHM OPTIMIZATION PROCESS



Using the synthetic data set the calculation of TFA target contrast was automated and optimization possible. The merit function using Michelson contrast was:

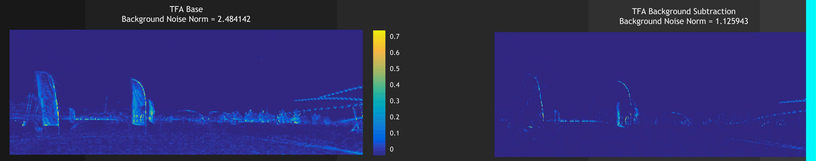
$$\varphi = 1 - C = 1 - \left(\frac{I_{max} - I_{min}}{I_{max} + I_{min}}\right)$$

This figure shows the progression for a binary genetic algorithm optimization with 100 individuals and 30 filter coefficients. Low to mid spatial frequencies provide the most information for TFA.

TFA Signal Optimization

Upon examination of collected data, it was found that the decorative flags placed around the field were c
background noise. A new method of cleaning the data was created that follows the same concepts as standard
subtraction; however, instead of subtracting off a background frame from the raw data video, a background TFA
shown as the TFA Base is removed.

TFA VS. STANDARD BACKGROUND IMAGE SUBTRACTION AND TFA BACKGROUND SUBTRACTION FOR FLAGS IN 15MPH WINDS



A background TFA frame is slightly different than a standard background frame. A standard background fra
constant items in the image, the background scene. However, a TFA background image shows the consistent
constant background is already removed. By subtracting a TFA background from the scene, the waving flags cau
winds can be nearly removed. While TFA limits this noise inherently, the TFA background subtraction reduces the

Machine Learning in the TFA Domain

RESULTS SHOWING THE IMPROVEMENTS OF THE TFA CLASSIFIER

a) Raw Image

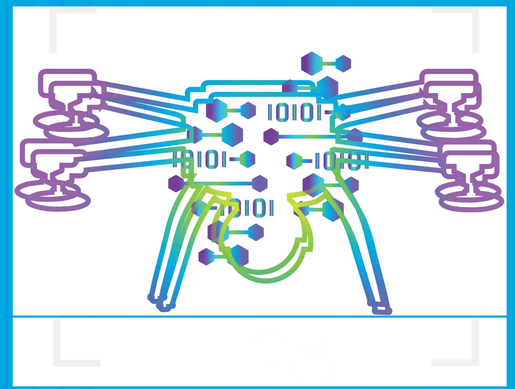
b) Original TFA

c) Improved TFA

Previously, TFA machine learning consisted of a convolutional neural network (CNN) classifying an en
determine if an UAS was present. This had negative results when multiple targets were in the scene with th
iteration, the team decided to pursue object detection using a regional CNN (R-CNN) due to its ability to
boxes around the object of interest located within the image. With the large amount of data, computation
time needed to train an R-CNN from scratch, an existing network was utilized which was then transfer learn
domain. The network that was carried out goes by the name You Only Look Once (YOLO) due to the way
predicts the bounding boxes and probabilities.

Results

TFA is designed to monitor subtle changes in the positions of pixels in video-data and distinguish these frequencies from the frequencies of other biological entities. This advanced detection capability allows operators to clearly identify small targets in cluttered environments.



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Publication

Video

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