Georgia Tech Research Institute

EMADE for Intelligence Surveillance and Reconnaissance Applications

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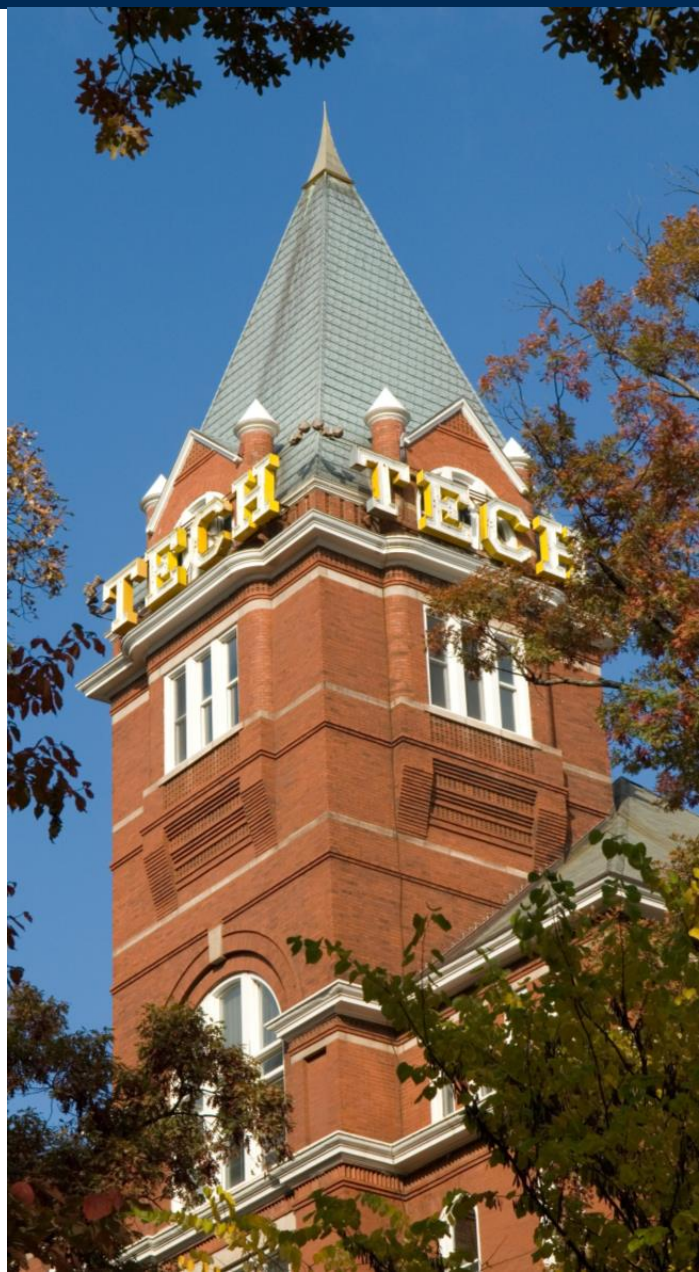


EMADE Successes

CTTSO Combating Terrorism Technical Support Office

Vetrax

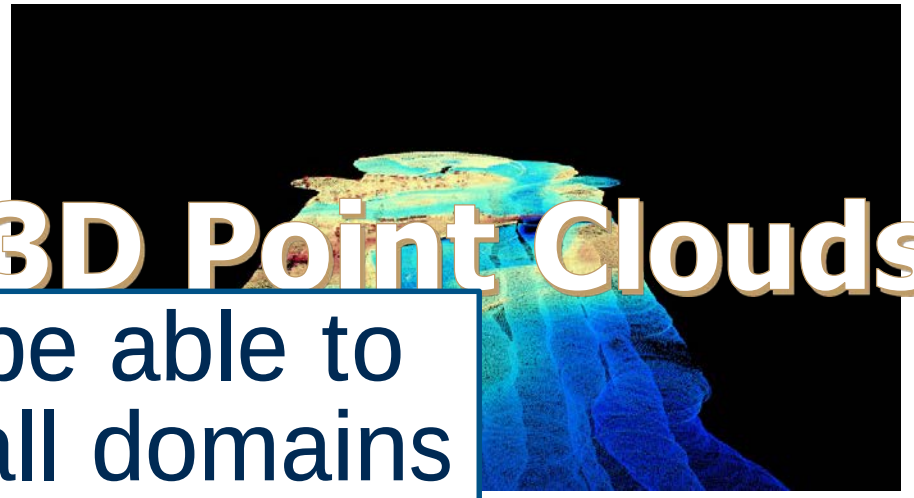
Georgia Research Alliance

Better mission planning for first responders = Lives saved

Objective measurements of behaviors = A voice for dogs

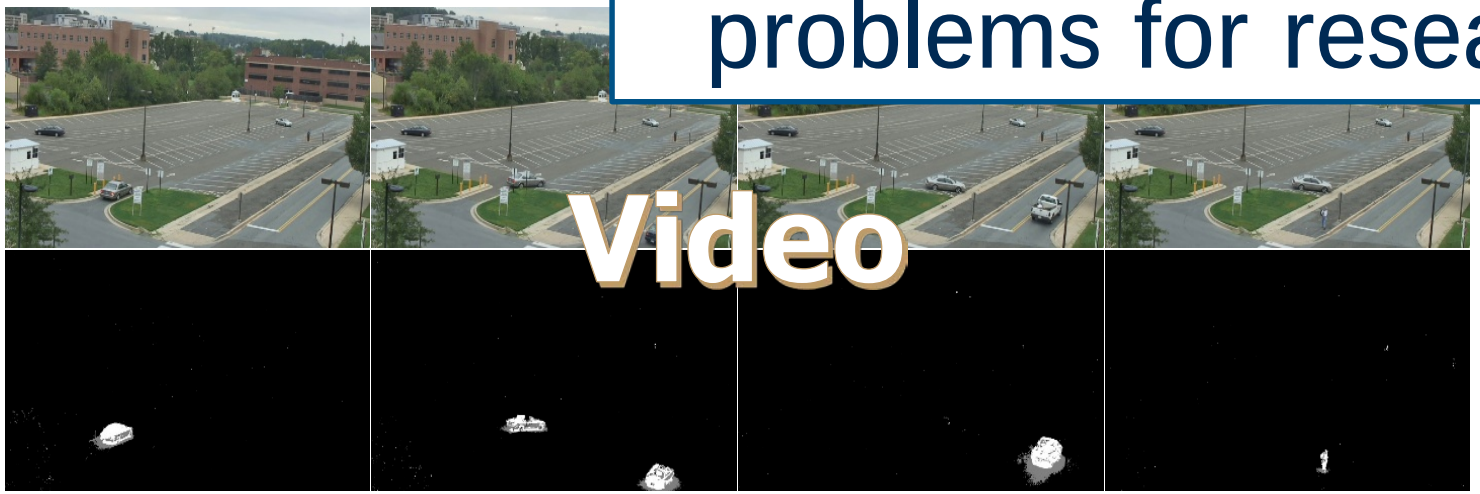
Expanding EMADE's Applicability

Intelligence Surveillar



ud Processing

Our vision is to be able to apply EMADE to all domains that pose challenging problems for researchers



Automated Vehicle & Personnel Detection

Radar Emitter Classification

Classification	Regression	Ensemble
k-Nearest Neighbor Classifier	k-Nearest Neighbor Regressor	Adaboost
Support Vector Machine Classifier	Support Vector Machine Regressor	Bagged Learner
Decision Tree Classifier	Decision Tree Regressor	ExtraTrees
Random Forest Classifier	Random Forest Regressor	XGBoost [47]
Naive Bayes Classifier	Gradiant Boosting Regressor	
Logistic Regression Classifier		
Gaussian Mixture Model Classifier	LightGBM [48]	
Best Linear Unbiased Predictor		
Orthogonal Matching Pursuit		
KMeans		
Stochastic Gradient Descent		
Passive Aggressive Classifier		

22 Machine Learning

Windowing Functions	Filters	Transforms	Math Functions
Hann	Averaging	Discrete cosine transform	Autocorrelation
Hamming	Difference	Fast Fourier transform	p-Norm
Tukey	Kalman	Discrete wavelet transform	Root mean square
Cosine	Wiener	Principal component analysis	Sum
Lanczos	Savitzky-Golay	Independent component analysis	Cumulative sum
Triangular		Sparse principal component analysis	Product
Bartlett		Linear predictive coding	Cumulative product
Gaussian		Empirical cumulative distribution function	Absolute value
Bartlett Hann			Log
Blackman			Arcsine
Kaiser			Arccosine
Planck Taper			Arctangent
Nuttall			Sine
Blackman Harris			Cosine
Blackman Nuttall			Tangent
Flat top			Exponential
			Cross correlation

46 Signal Processing

Clustering	Affinity propagation	Mean shift	Dbscan	Spectral
	K-means	Agglomerative	Birch	
Feature Selection	K-Best	Percentile	Fpr	Fdr
	Generic Univariate	Fwe	Varience Threshold	
Image Processing	Minimum to zero	To uint8	To uint8 scaled	To float
	To Float normalize	Edge detection Canny	Corner detection Harris	Corner detection min eigenval
	Highpass Fourier ellipsoid	Lowpass Fourier shift	Highpass Fourier shift	Highpass Fourier Gaussian
	Highpass Fourier uniform	Highpass unsharp mask	Highpass Laplacian	Highpass Sobel derivative
	Lowpass filter median	Median blur	Lowpass filter average	Blur
	Lowpass filter Gaussian	Lowpass filter bilateral	Lowpass Fourier elipsoid	Lowpass Fourier Gaussian
	Lowpass Fourier uniform	Threshold binary	Threshold to zero	Morph erosion rect
	Morph erosion ellipse	Morph erosion cross	Morph dilate rect	Morph dilate ellipse
	Morph dilate cross	Morph open rect	Morph open ellipse	Morph open cross
	Morph close rect	Morph close ellipse	Morph close cross	Morph gradient rect
	Morph gradient ellipse	Morph gradient cross	Morph tophat rect	Morph tophat ellipse
	Morph tophat cross	Morph blackhat rect	Morph blackhat ellipse	Morph blackhat cross
	Contours all	Contours min area	Contours max area	Countours convex concave
	Contours min length	Contours max length	Contour mask	Contour mask min area
	Contour mask max area	Contour mask convex	Contour mask min length	Contour mask max length
	Contour Mask range length	Contour mask min enclosing circle	Contour mask max enclosing circle	Contour mask min extent enclosing circle
	Contour mask max extent enclosing circle	Contour mask range extent enclosing circle	Contour mask min aspect ratio	Contour mask max aspect ratio
	Contour mask range aspect ratio	Contour mask min extent	Contour mask max extent	Contour mask range extent
	Contour mask min solidity	Contour mask max solidity	Contour mask range solidity	Contour mask min equ diameter
	Contour mask max equ diameter	Contour mask range equ diameter	Threshold n largest	Threshold n largest binary

7 Clustering
7 Feature Selection
80 Image Processing

Caching

- Subtrees are exchanged constantly through the evolutionary process, meaning many individuals process the same data.

- For expensive primitives, we cache results on disk by...
  1. Compute a hash of the input data to the primitive:
     - E.g., b94d27b9934d3e08a52e52d7da7dabfac484efe37a5380ee9088f7ace2efcde9
  2. Create a unique identifier by combining the hash with the primitive name and input parameters:
     - E.g., knn_3_ b94d27b9934d3e08a52e52d7da7dabfac484efe37a5380ee9088f7ace2efcde9
  3. If the hash exists on disk, read it in, else write it after processing.

- Each generation clean the cache in a way to maximize benefit without exceeding storage:

  - $\sum_i r_i t_i$,

  Where r is the hit rate of a unique identifier and t is the time it took to process initially.

Batched Learning

- Batched learning is useful for processing data piecemeal.
- Added the capability to EMADE to reduce memory usage when primitives allow for batched processing:
  - Signal processing algorithms such as DWT or FFT that do not require fitting
  - Machine learning algorithms that support batched learning:
    - Passive Aggressive Classifier
    - Stochastic Gradient Descent
    - Deep Neural Networks with Keras
    - Etc...
- Currently, batch size is an input to EMADE, and not something that is optimized.

xView Challenge

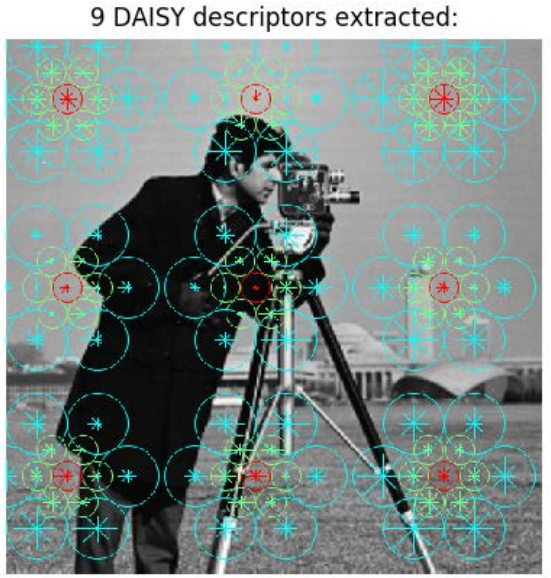
- Open overhead imagery challenge with a large dataset
  - 1 Million object instances
  - 60 Different object classes

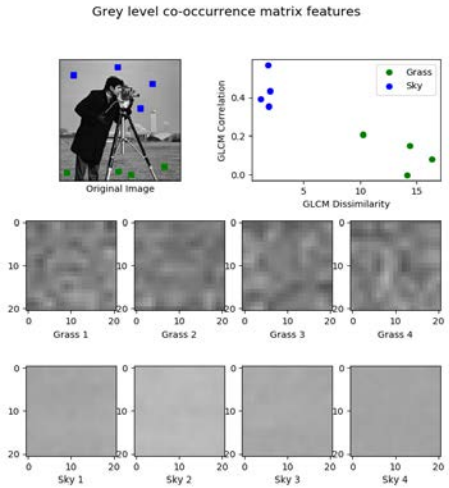
- We used the data to implement a binary classifier for buildings
  - Carved imagery into 224x224 pixel image chips
  - Predict a 1 when building in chip, 0 otherwise.

Intelligence Surveillance and Reconnaissance

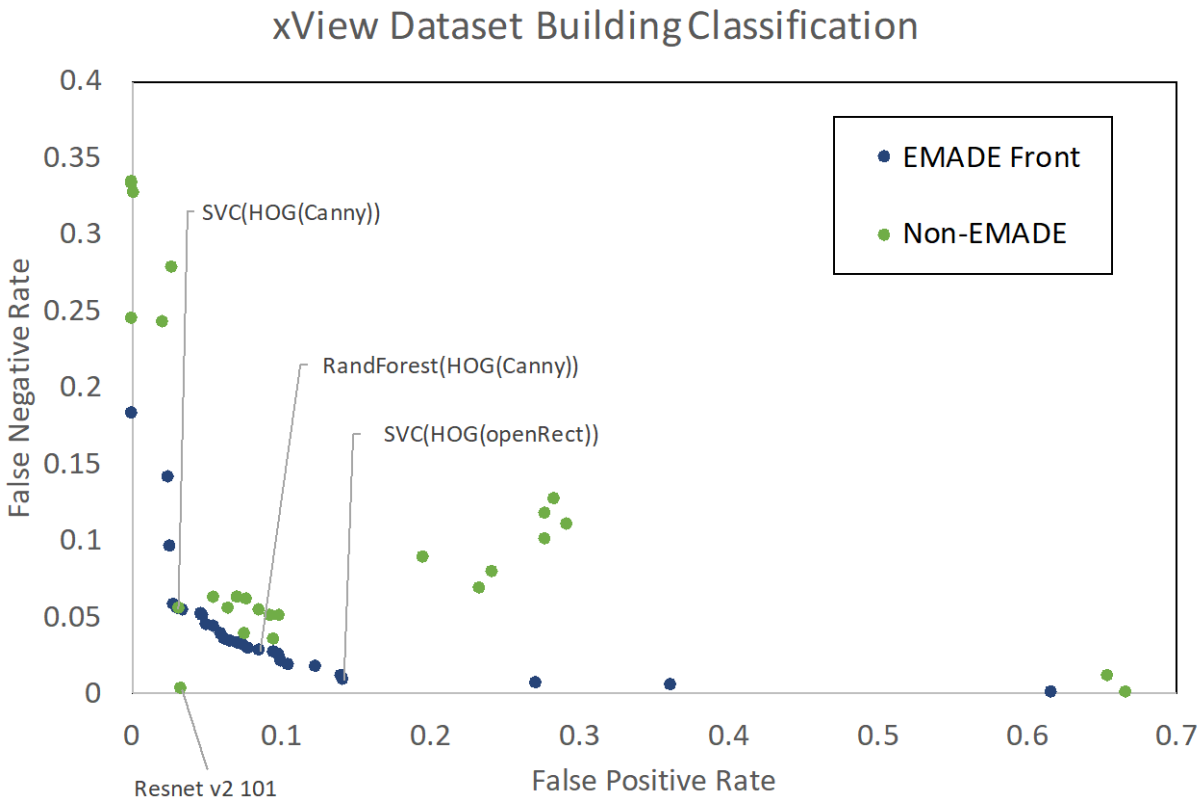
Traditional Computer Vision Techniques

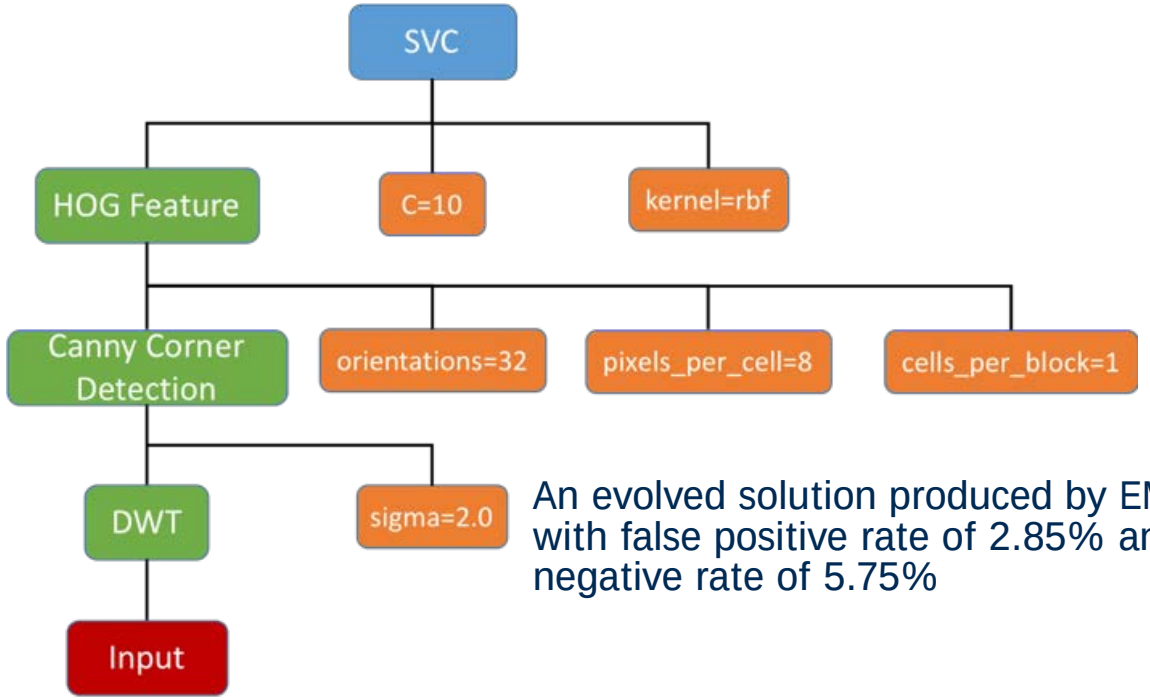
- Histogram of Oriented Gradients
- Daisy Features
- Canny Transform
- Grey Level Co-Occurrence Matrices





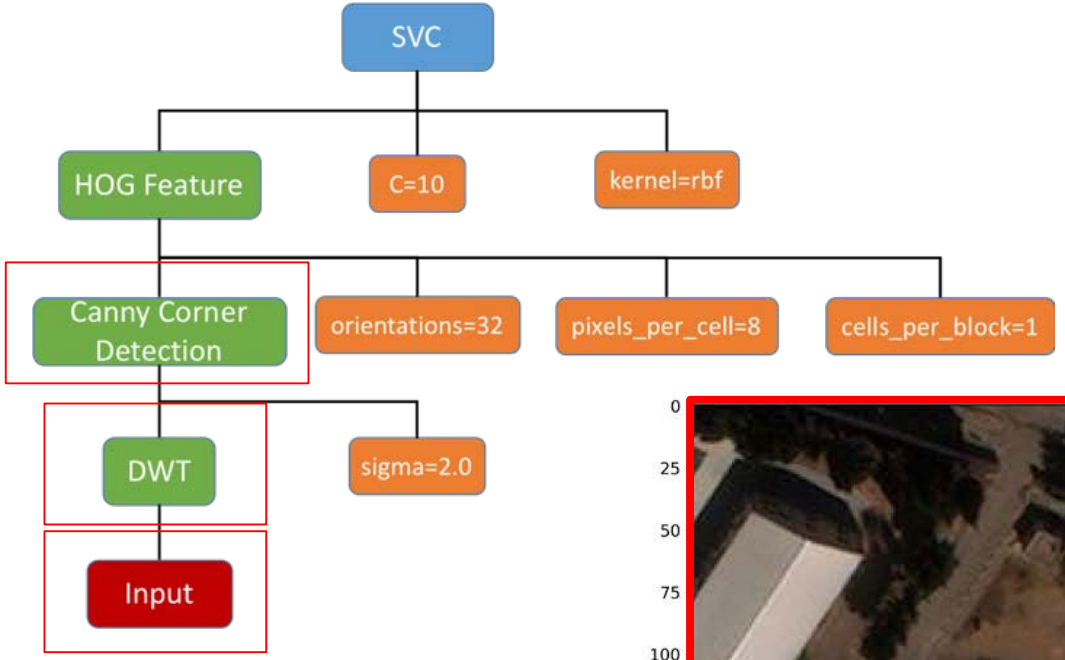
xView Results

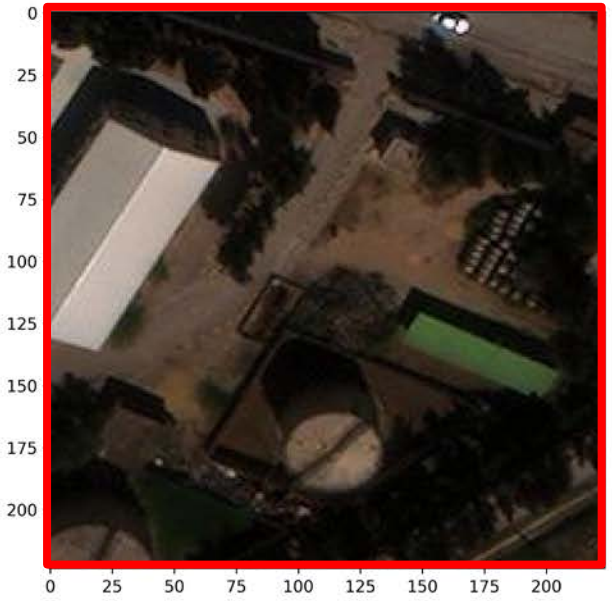


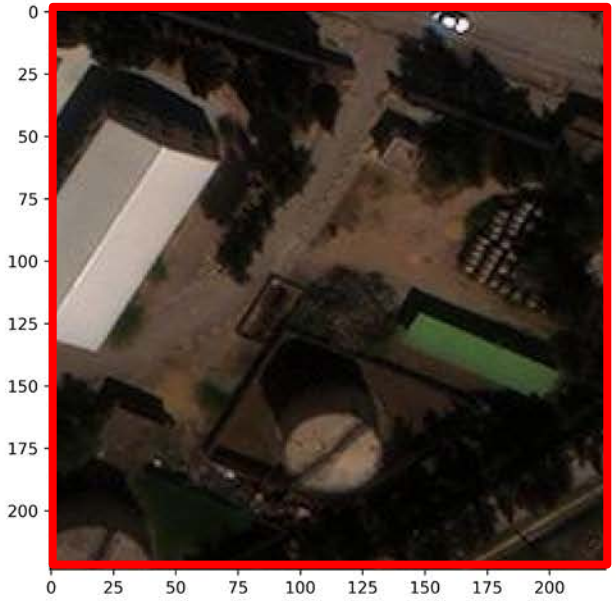


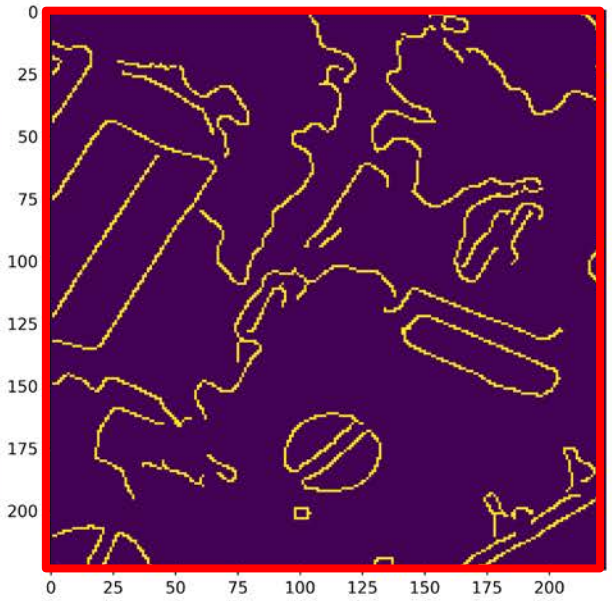
An evolved solution produced by EMADE with false positive rate of 2.85% and false negative rate of 5.75%

Example Data Flow









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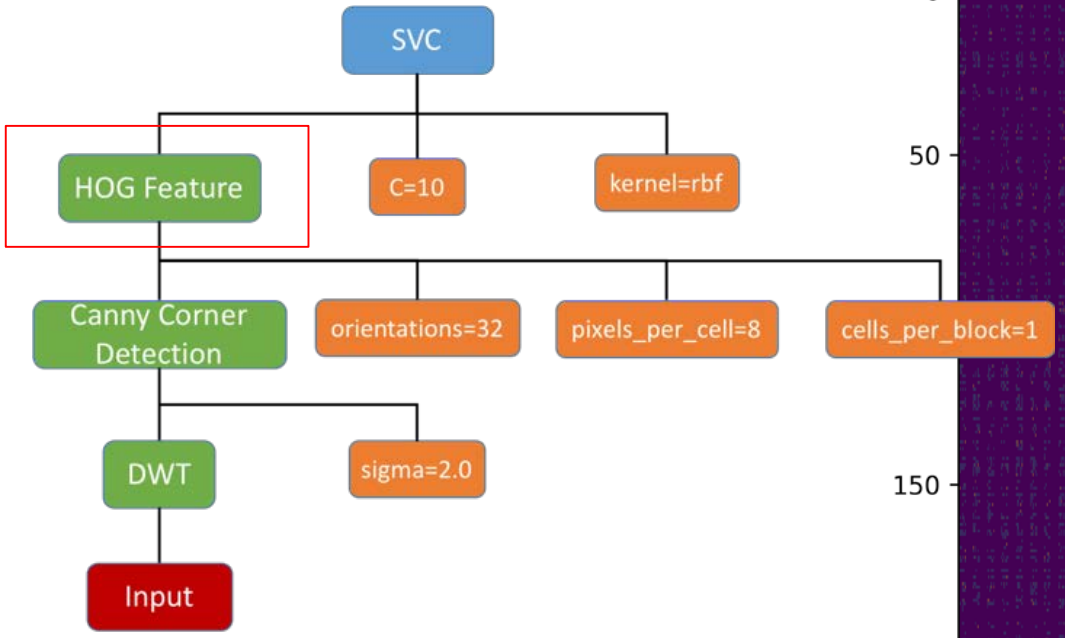
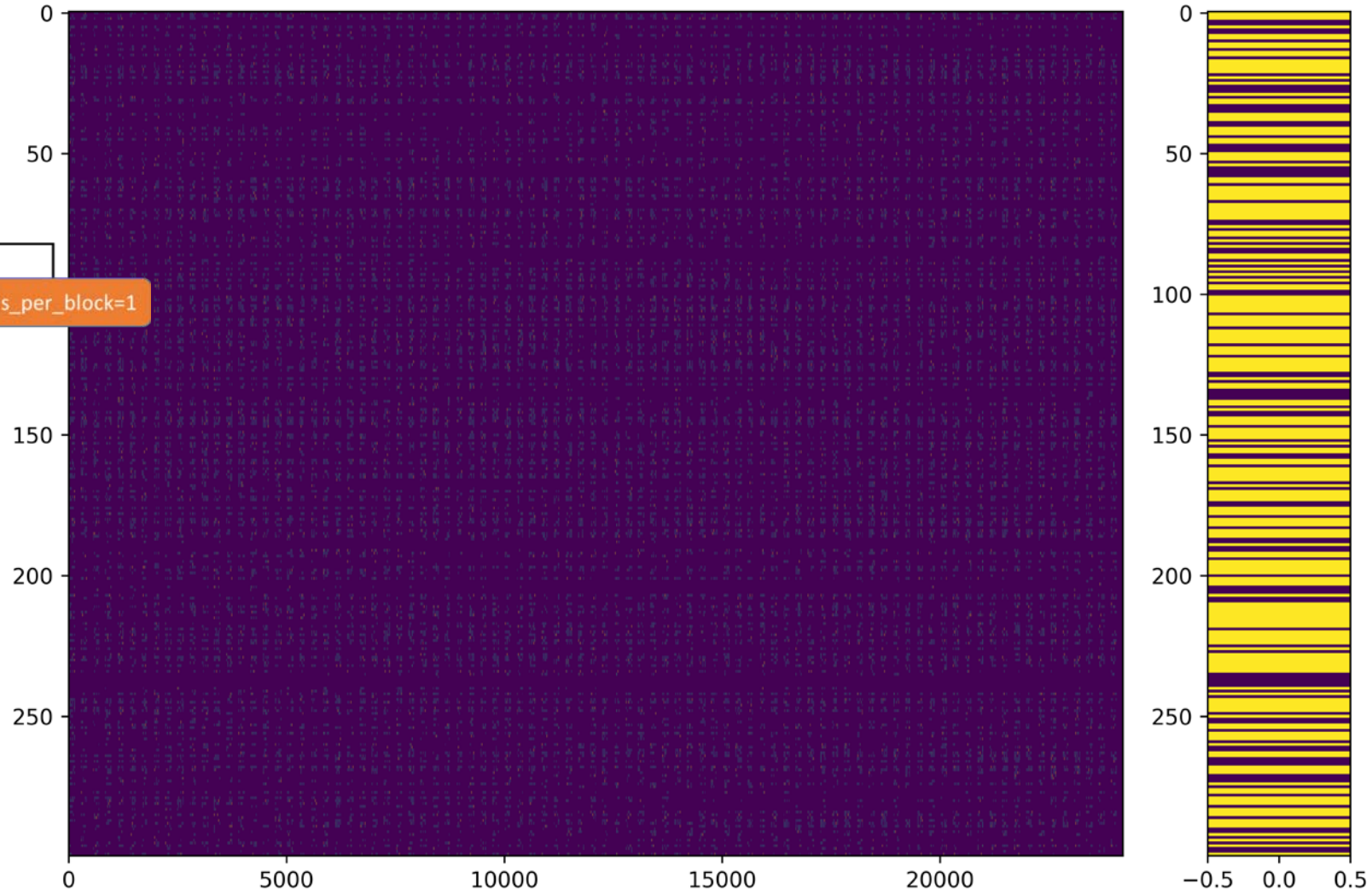


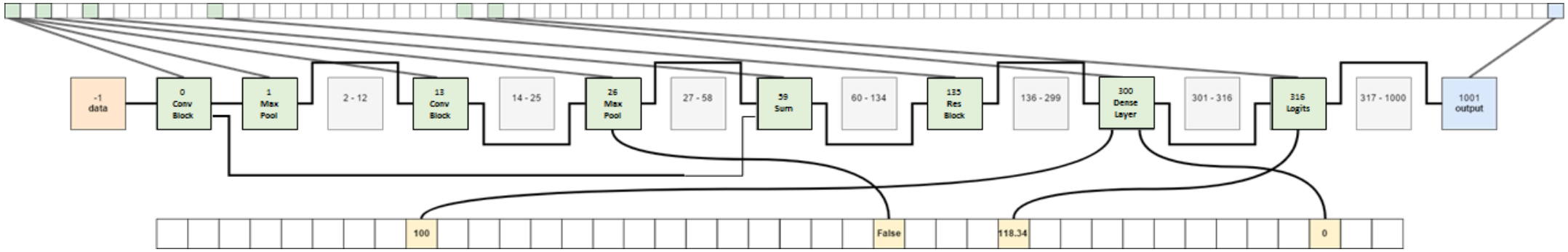


Analysis of Performance

- An evaluation on the first-tier dataset took EMADE on average 72.53 seconds, while the second-tier averaged 522.31 seconds.
- Out of 5,270 candidate algorithms, EMADE found 3053 that did not perform well enough to promote to the next tier.
  - This means the tiered dataset structure saved 381 CPU-hours of processing time at the expense of 44.66 CPU-hours of redundant computation on successful individuals.
- Over the course of the optimization, EMADE ran for a total of approximately 430 CPU-hours. Without a tiered structure, EMADE would have taken 765 CPU-hours.
  - Therefore, the tiered dataset structure offered a savings of about 44 percent.
- Our caching implementation netted 58 hours, which represents about a 12% improvement overall in EMADE throughput.

Path Forward: Deep Neural Networks

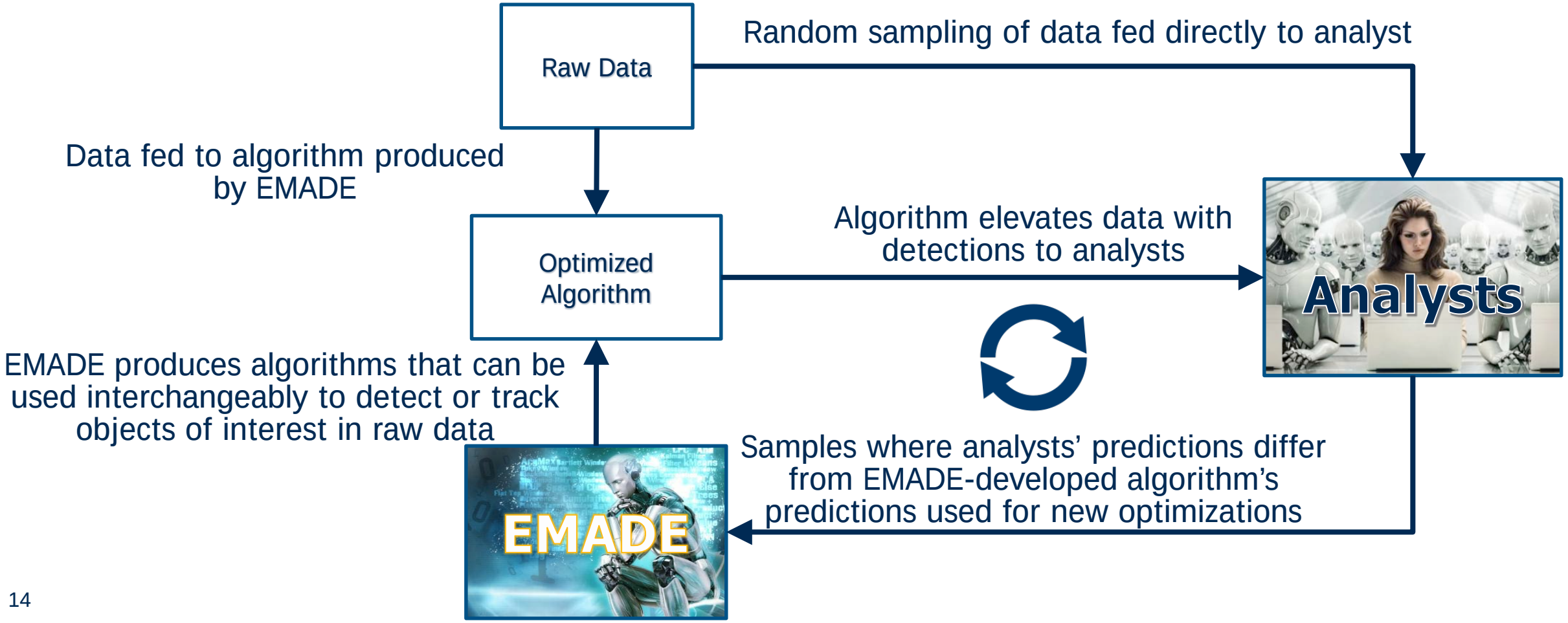
- Several different ways that DNN's can play a role in EMADE
  1. Implement pre-trained models as classifiers
  2. Train pre-trained models using transfer learning
  3. Optimize architectures and hyperparameters



- We recently began exploring all three paths forward for the "Army Signal Challenge", which involves classifying different RF signals.

Augmenting ISR Analysts with AutoML

- EMADE quickly adapts to new challenges as soon as new data is available

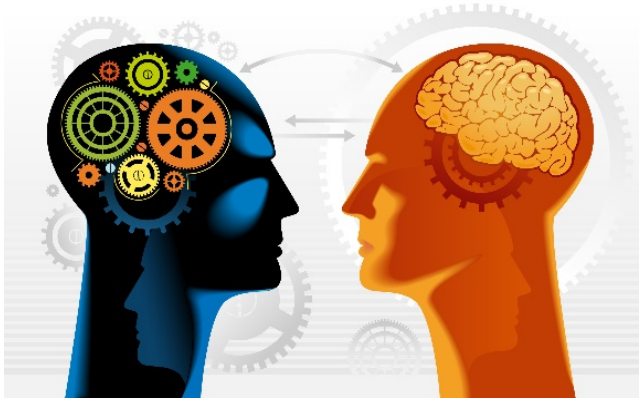


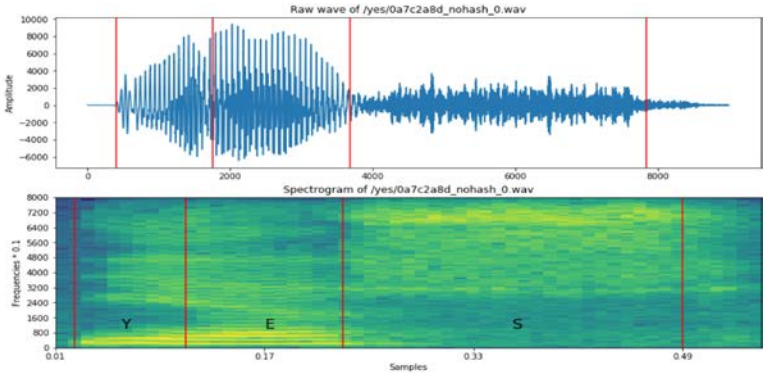
EMADE as a Fusion Engine

- Paradigm for EMADE is data in, algorithms out.
- EMADE allows data to flow freely through the tree structure.
- Fusion can be performed by allowing for multiple input sources within EMADE or as single data objects with multiple dimensions.
  - Truth data needs to be synchronized.
  - If performed as single data objects, primitives need to process the non-uniform arrays.

Vertically Integrated Projects

- Largest VIP team of 45+ students, 60+ students expected this spring
- Active development and application of our EMADE framework
- Resulted in 10 student assistants already deeply familiar with our work
  - 4 hold clearances





Quantitative Financial Analysis **Natural Language Processing** **Speech to Text**

Questions?