Introduction to Machine Learning in Remote Sensing

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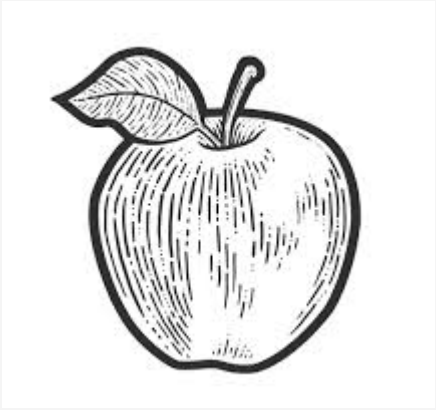
Contents

- What is Machine Learning
- Neural Network
- Types of Machine Learning
- Machine Learning in Remote Sensing
- Machine Learning in GEE

Apple or Orange

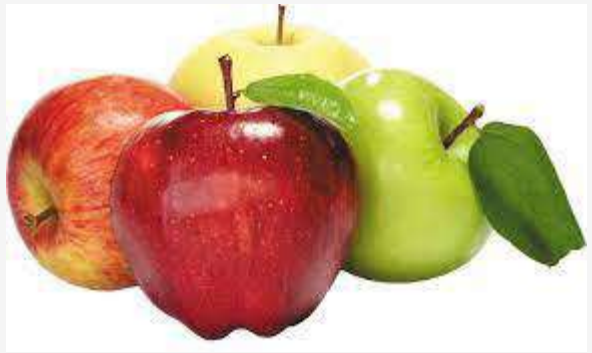
Simple Rule: Round Object with **Red**/**Orange** Color

Apple or Orange



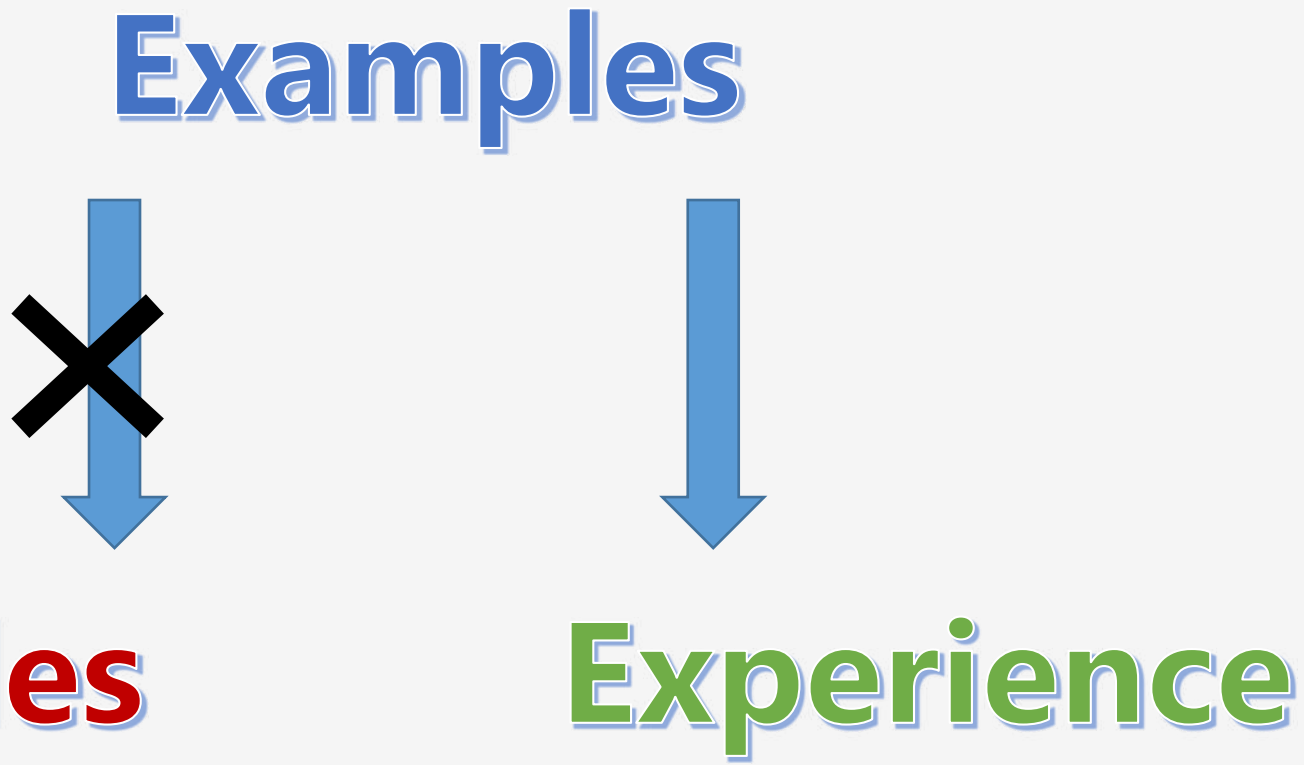
Simple Rule: ~~**Round Object**~~ with **Red**/**Orange** Color

Apple or Orange



Simple rules don’t always work.
Learn from examples, rather than apply simple rule

Apple or Orange



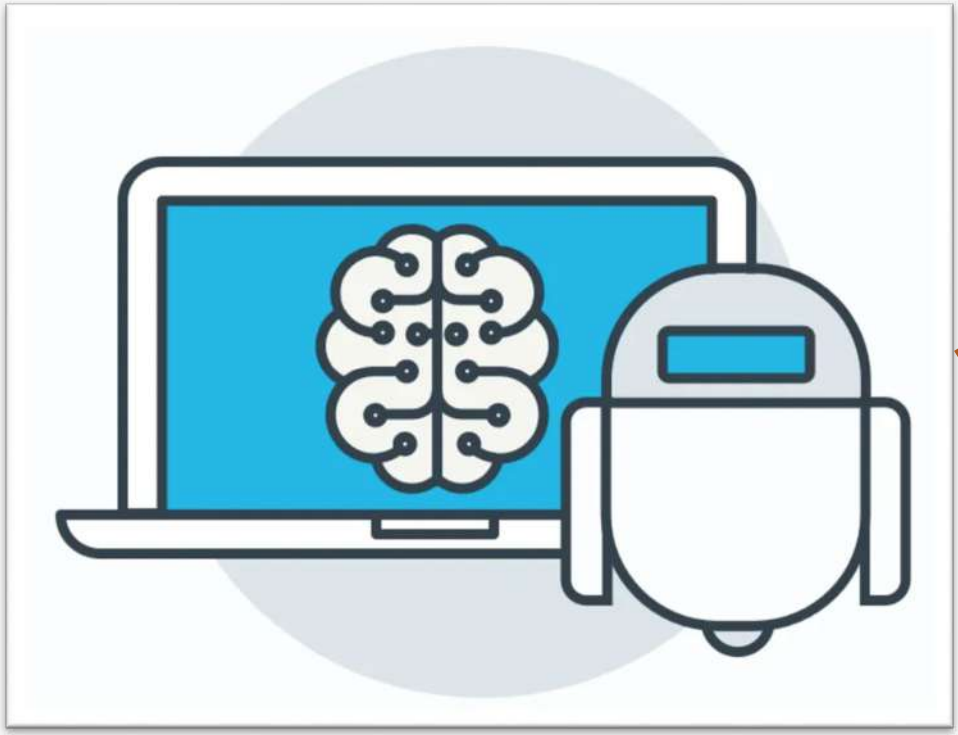
Simple rules don't always work.
Learn from examples, rather than apply simple rule

Apple or Orange

Use the instincts

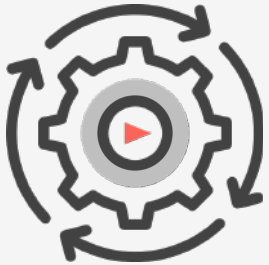
Introduction to Machine Learning

Algorithm



Input Data

Desired Result

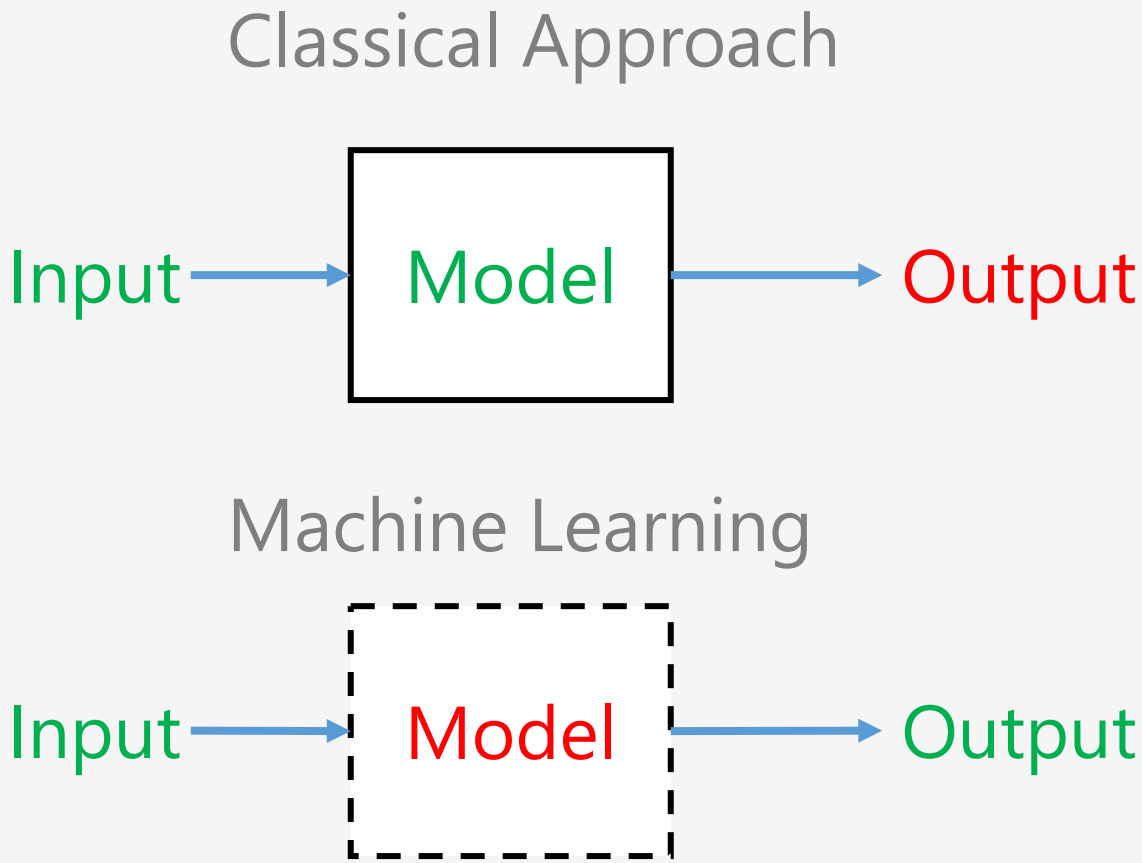


Automatic
Improve

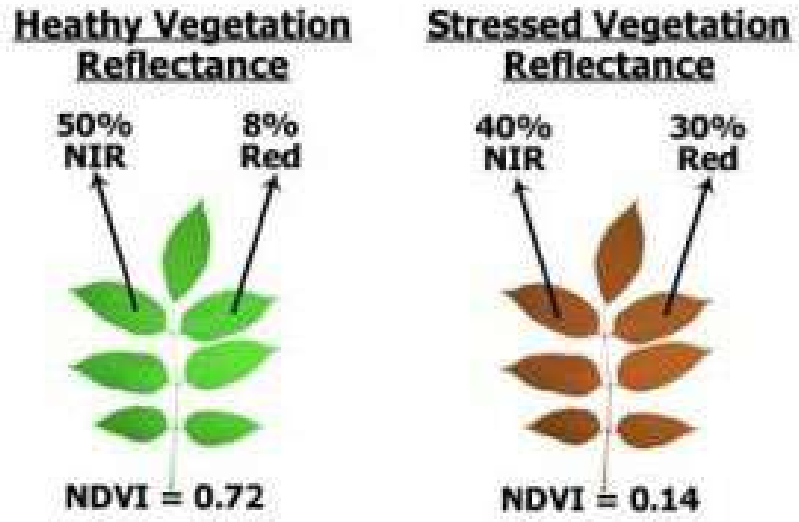
Machine Learning vs. Classical Approach

Given

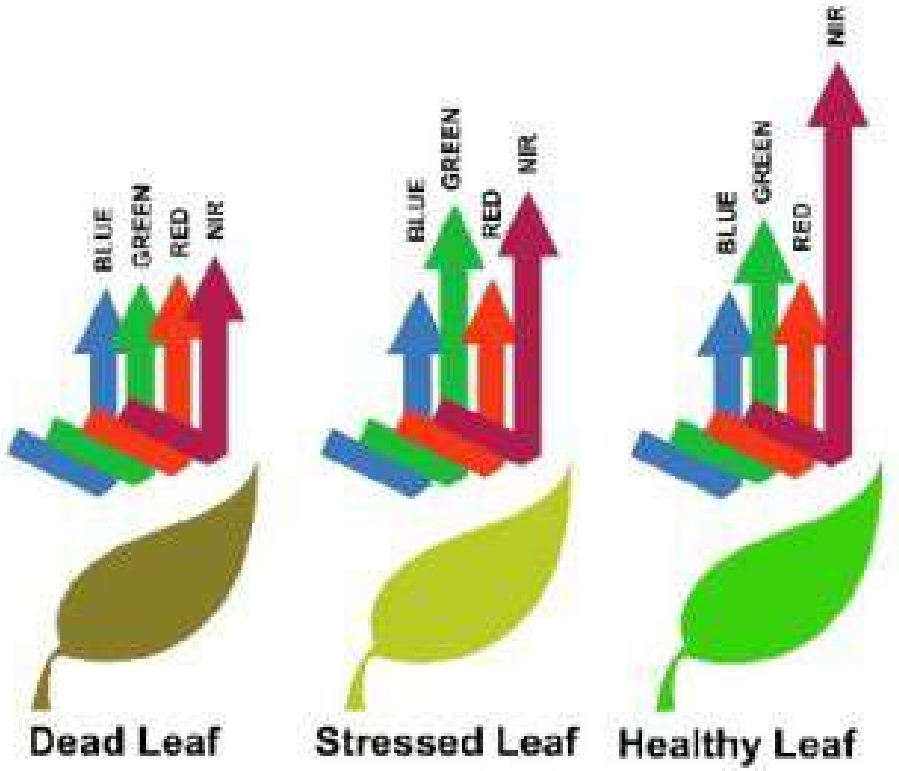
Wanted



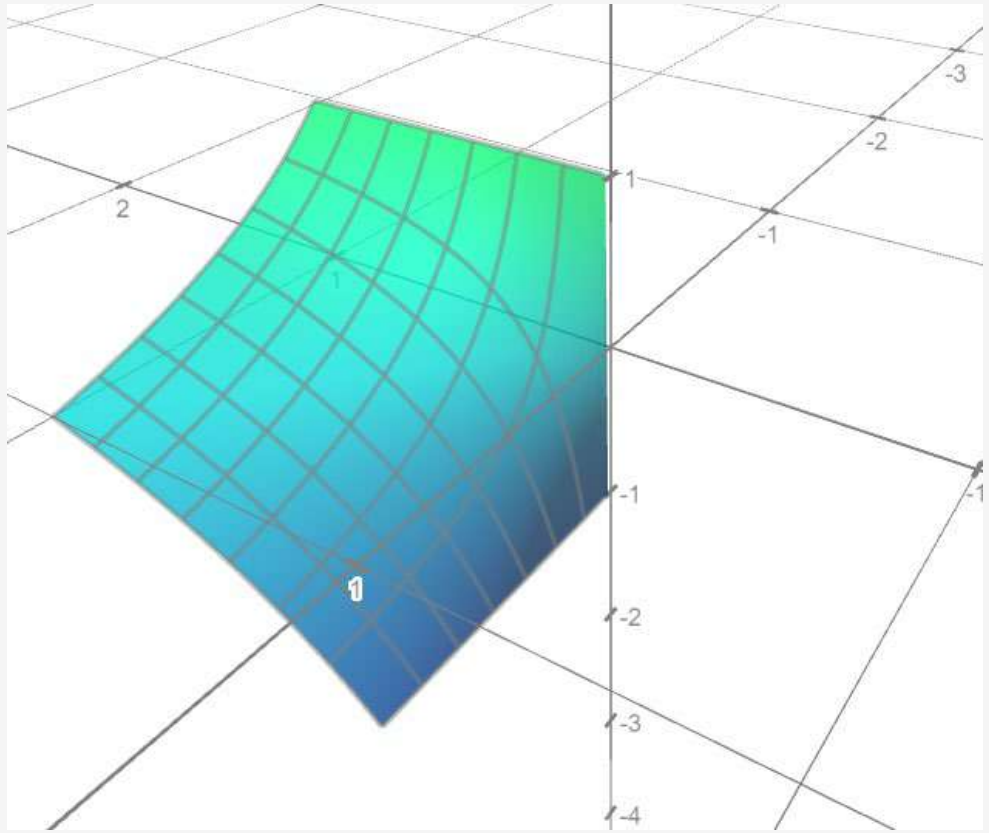
Classical Approach: NDVI



$$NDVI = \frac{NIR - Red}{NIR + Red}$$

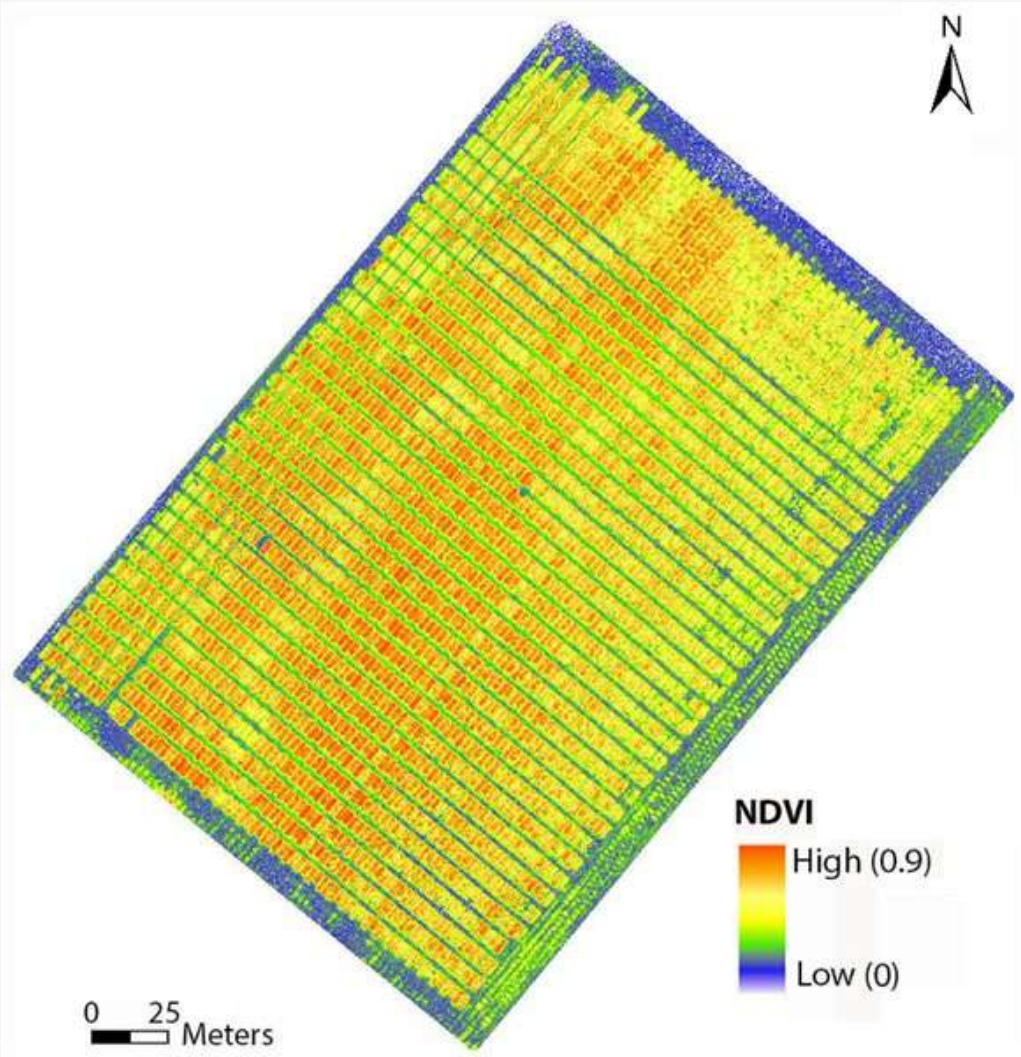


Classical Approach: NDVI

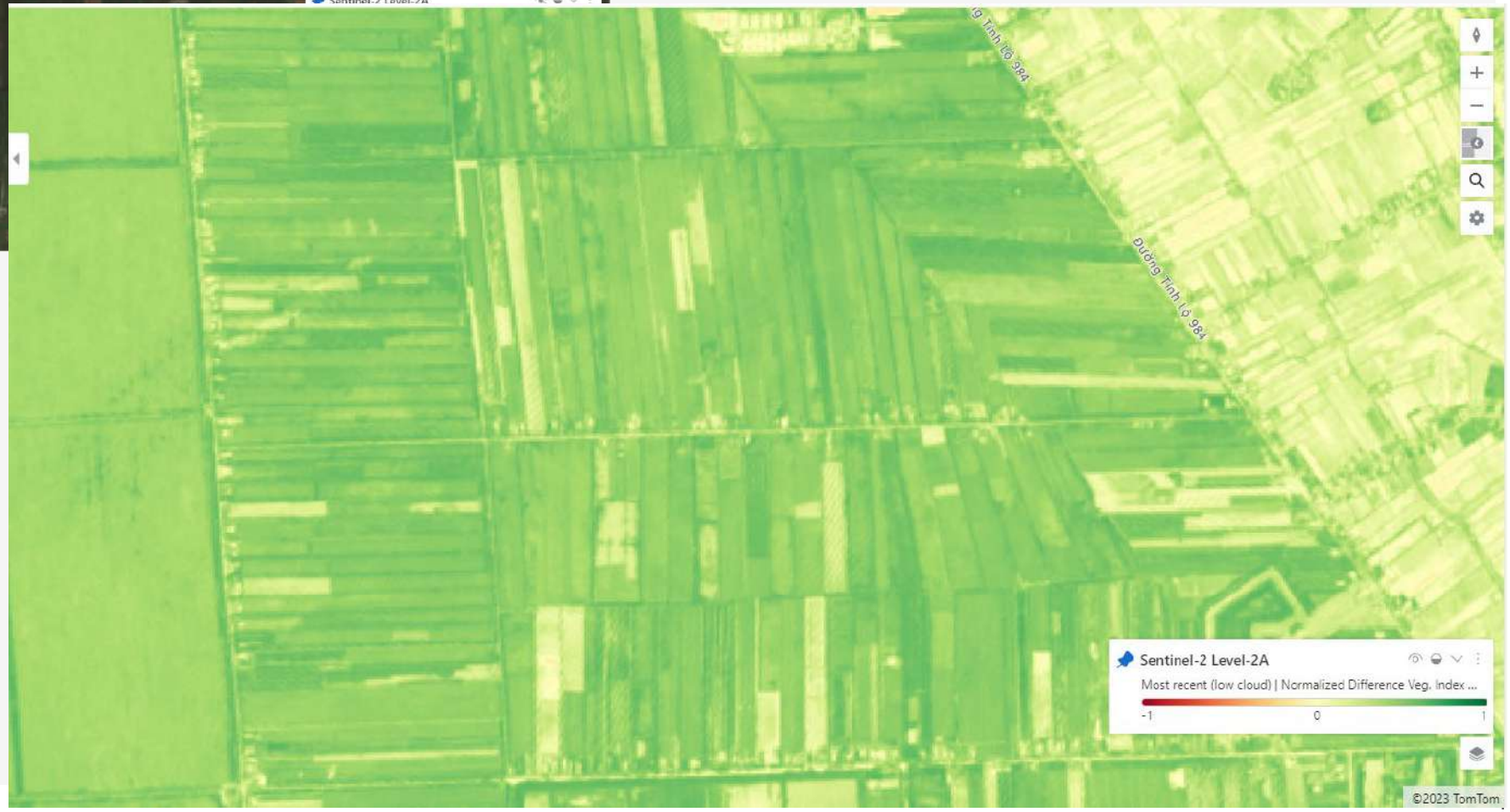


$$NDVI = \frac{NIR - Red}{NIR + Red}$$

$$z = \frac{x - y}{x + y}$$



https://www.math3d.org/eFIwbcirR



https://t.ly/xpbgY

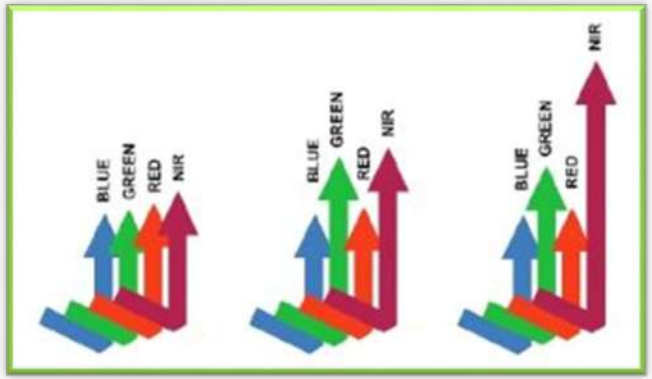
Classical Approach: NDVI

Given

Wanted

Classical Approach

Input → Model → Output



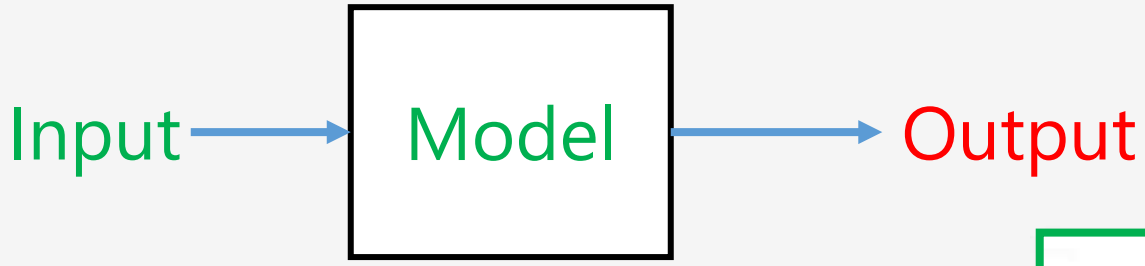
$$NDVI = \frac{NIR - Red}{NIR + Red}$$

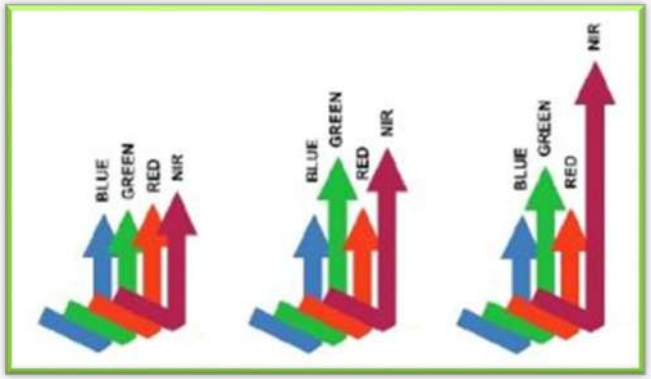
Machine Learning vs. Classical Approach

Given

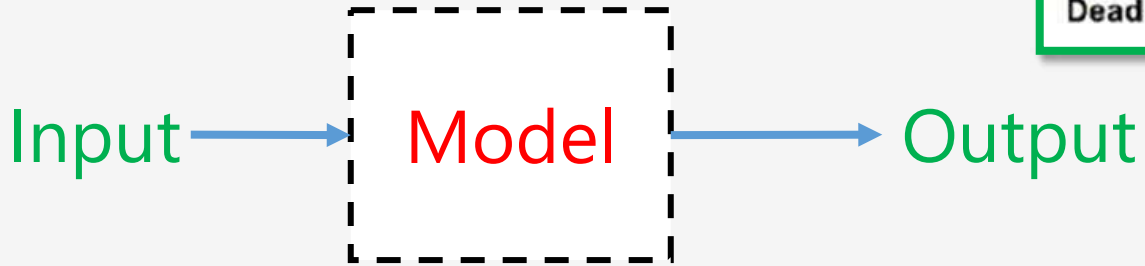
Wanted

Classical Approach





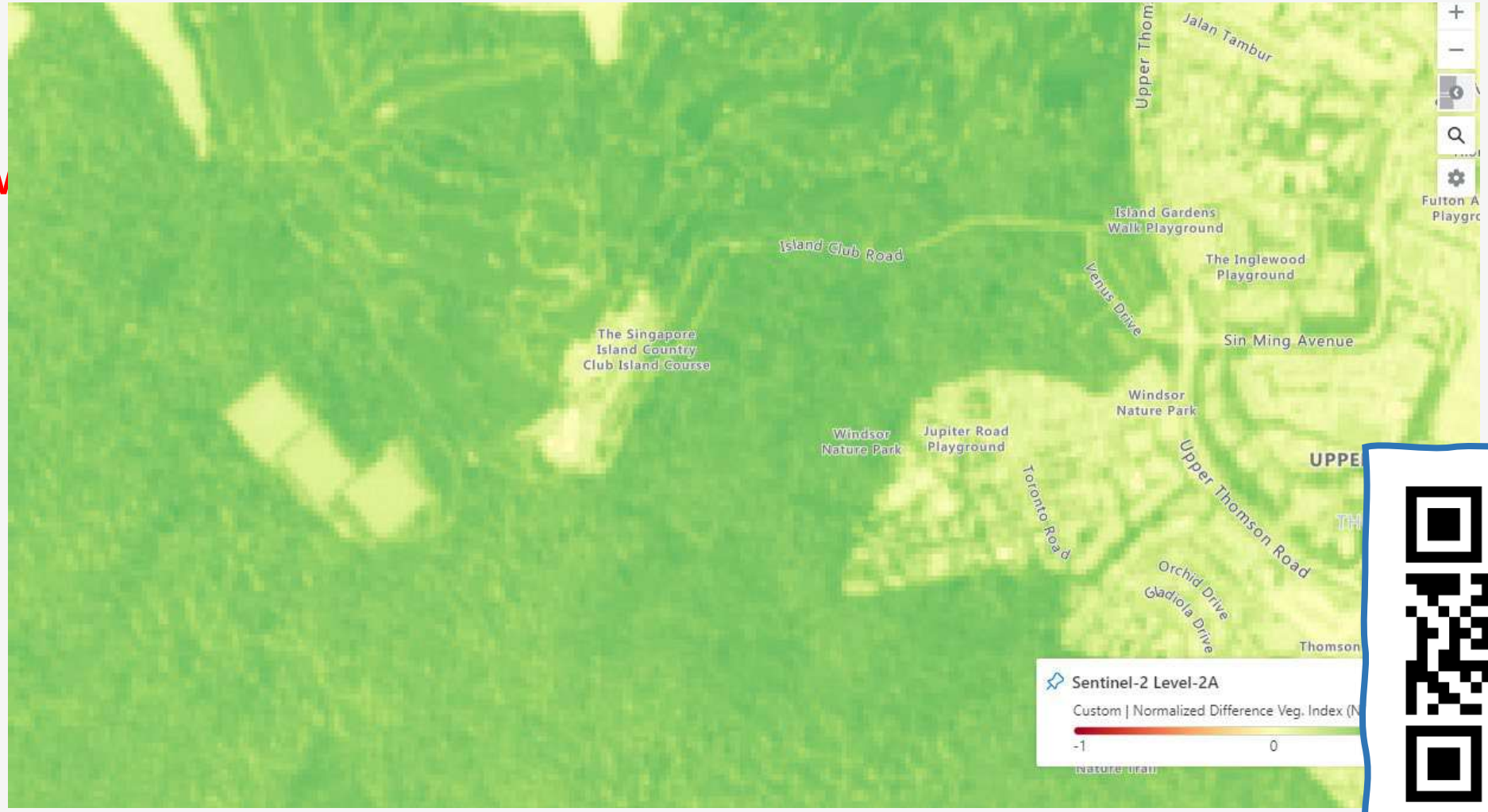
Machine Learning



Classical Approach: Tree/Grass Classification

G

W



https://www.menti.com/alaf1t425d72


The Singapore Island Country Club Island Course
Sentinel-2 Level-2A
Custom | Natural color
©2023 TomTom

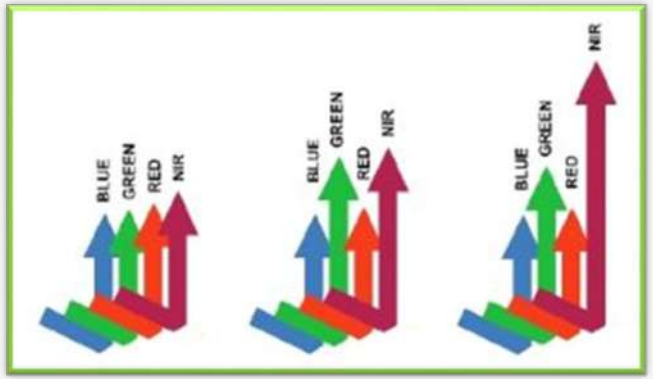
Classical Approach: NDVI

Given

Wanted

Classical Approach

Input → Model → Output

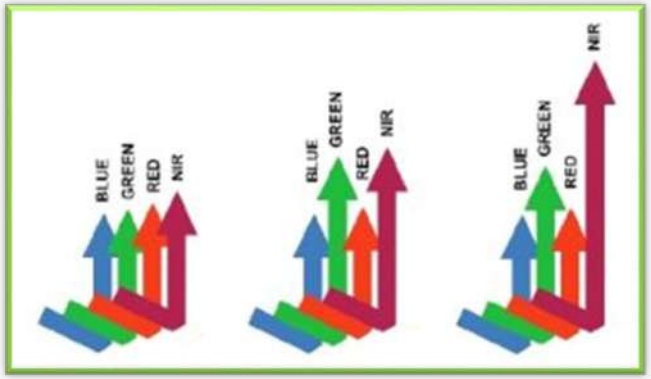


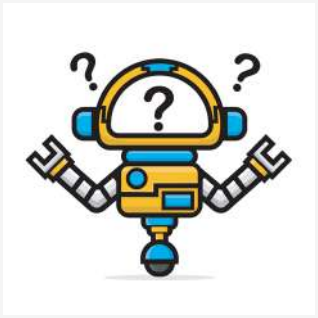
New Formula

Machine Learning vs. Classical Approach

Given

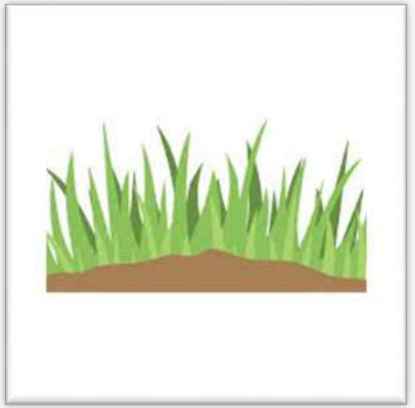
Wanted





Machine Learning

Input → Model → Output

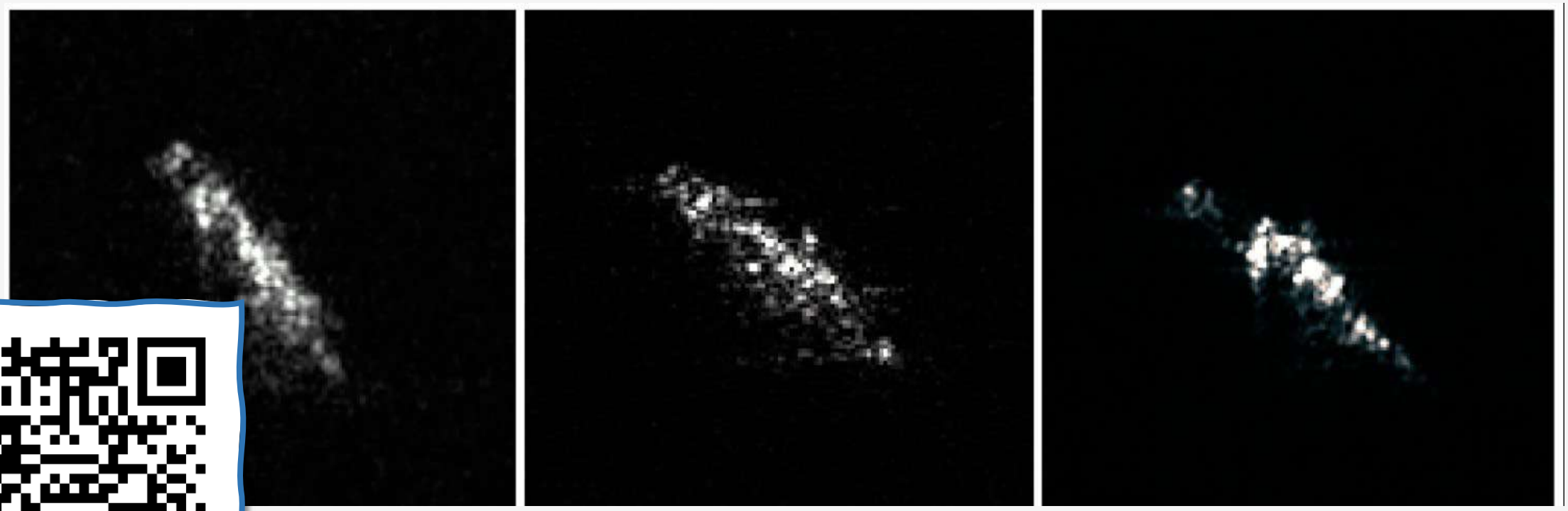


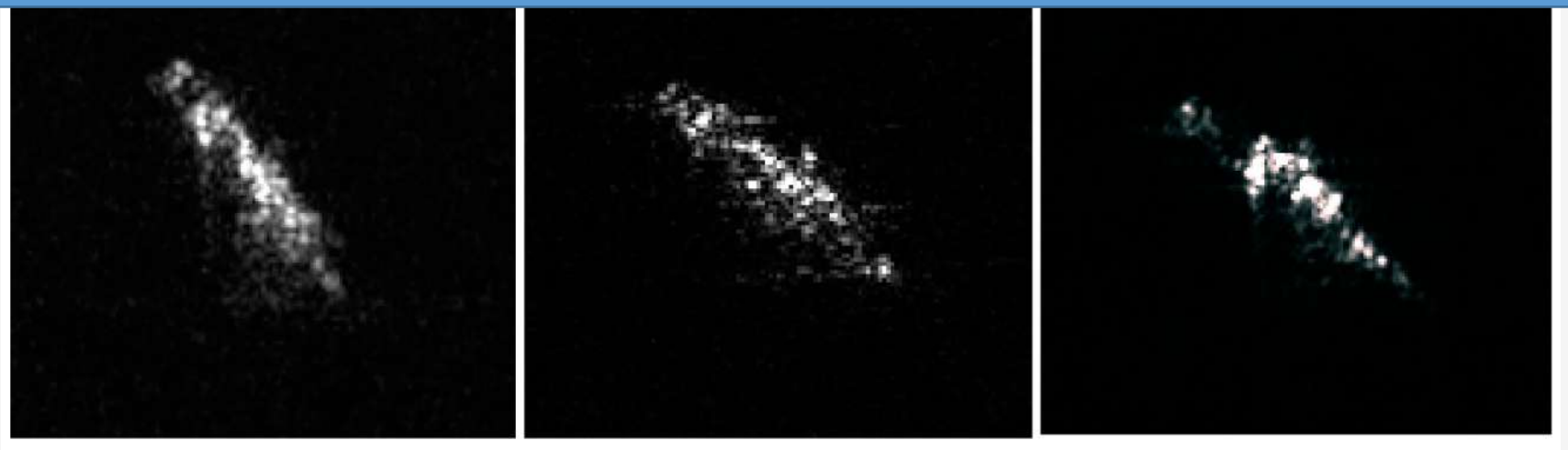
Manually Defined Decision Tree

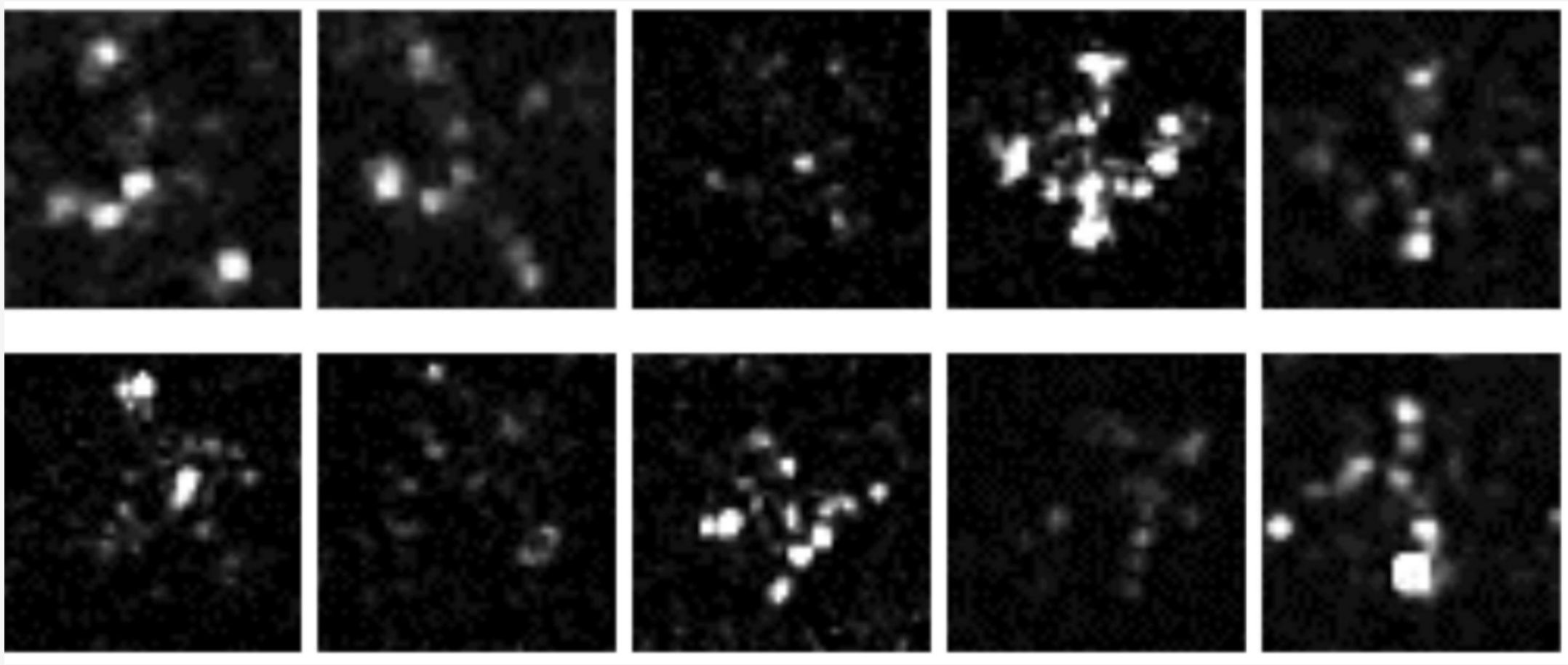
SE Shallow Sea
SB Silt Beach
ST Scirpus Triqueter Salt Marsh
SA Spartina Alterniflora Salt Marsh
FH Freshwater Herbaceous Marsh
WB Water Body
AP Aquaculture Ponds
PF Paddy Field
DF Dry Field
IS Impervious Surface
FO Forest
BL Bare Land
SP Salt Pan

Harder Task

Harder Task: SAR Classification







What does "learning" mean?

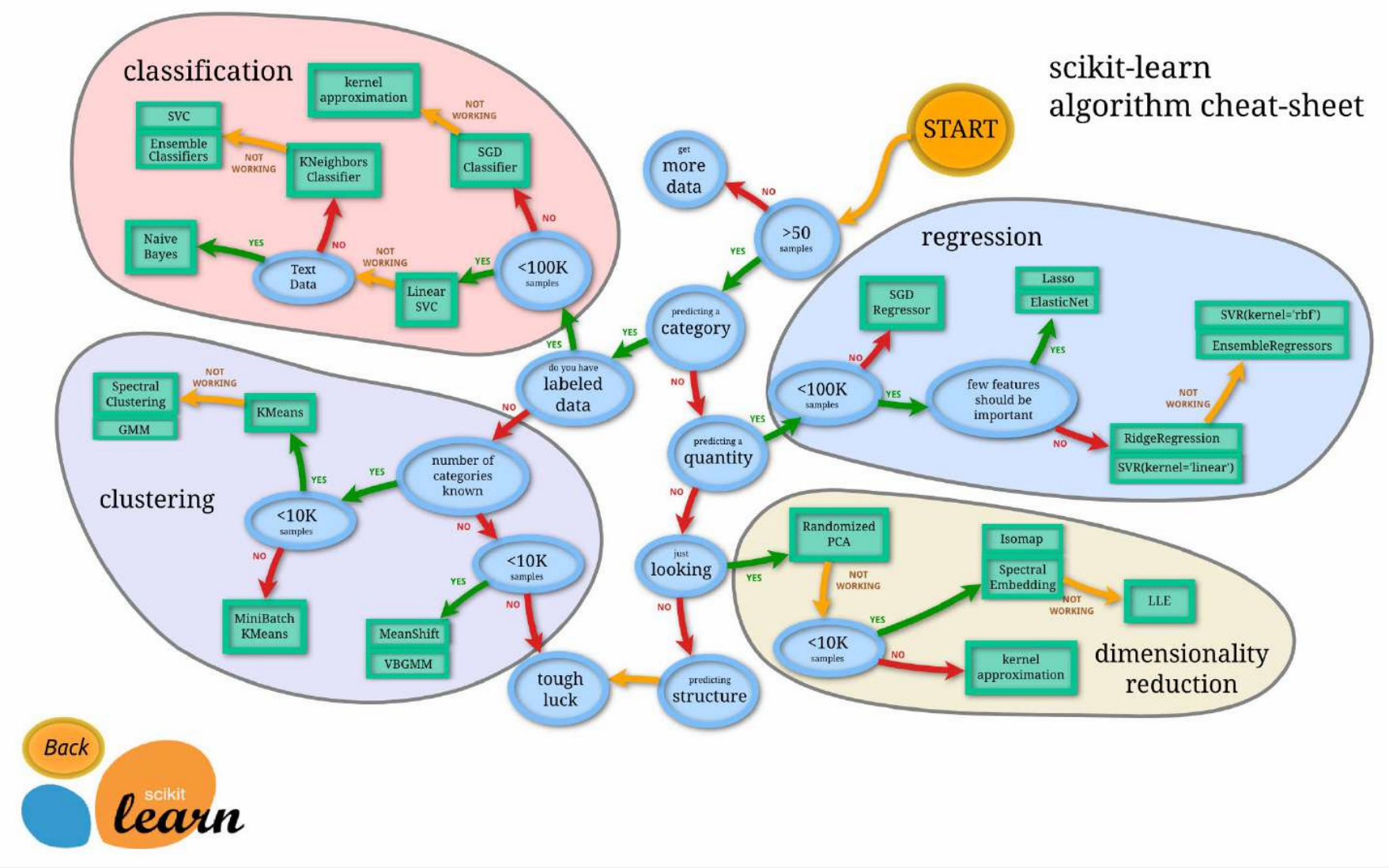
``Learning denotes changes in the system that are adaptive in the sense that they enable the system to do the task or tasks drawn from the same population **more efficiently and more effectively the next time**.''

-- Herbert Simon

Try to minimize cost function

Machine learning: a computer has learned something after it enhanced the performance of doing something without changing program.

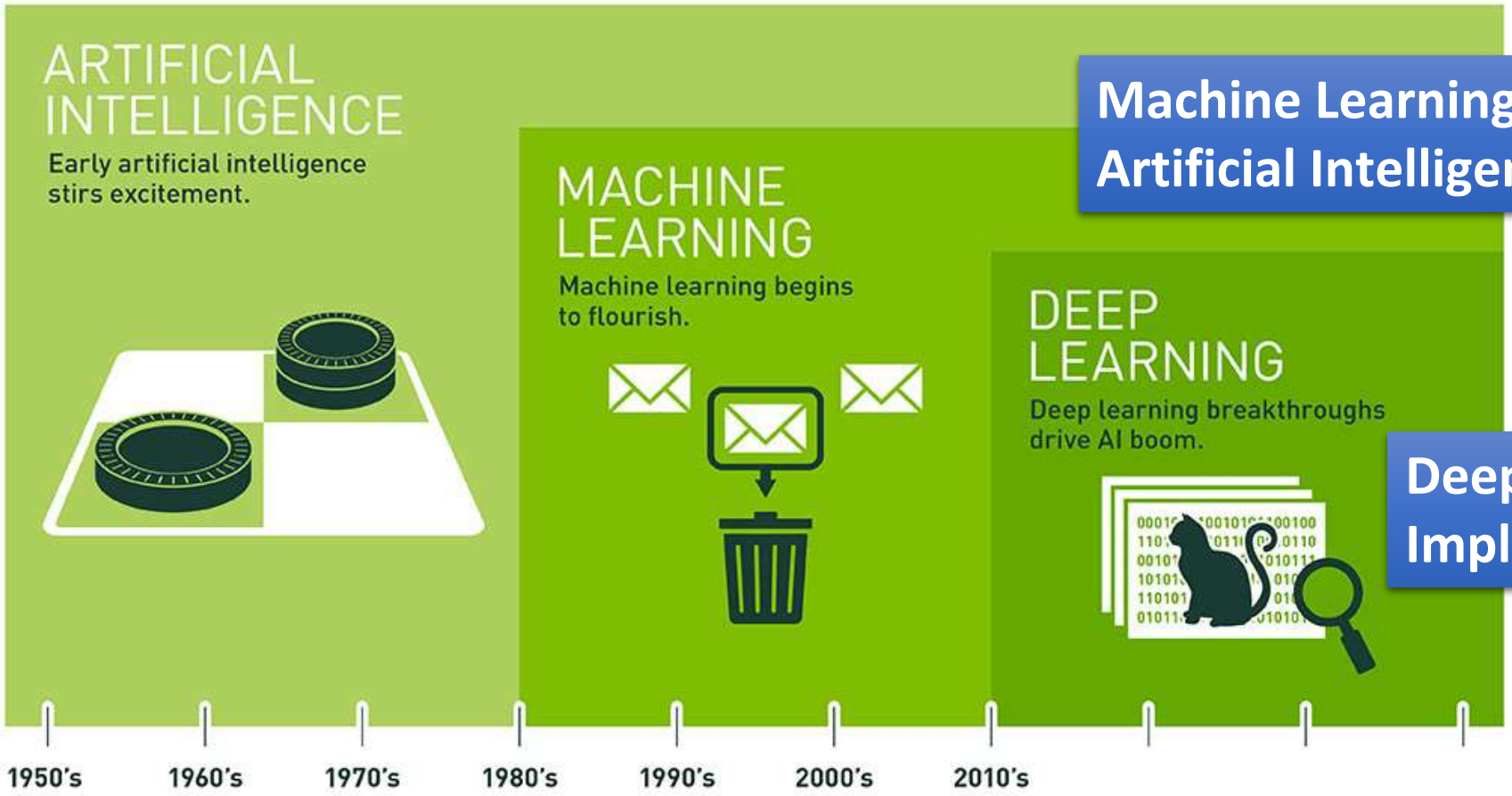
Classical Machine Learning Methods



https://scikit-learn.org/stable/tutorial/machine_learning_map/index.html

Deep Learning

Artificial Intelligence — Hand-coded Human Intelligence

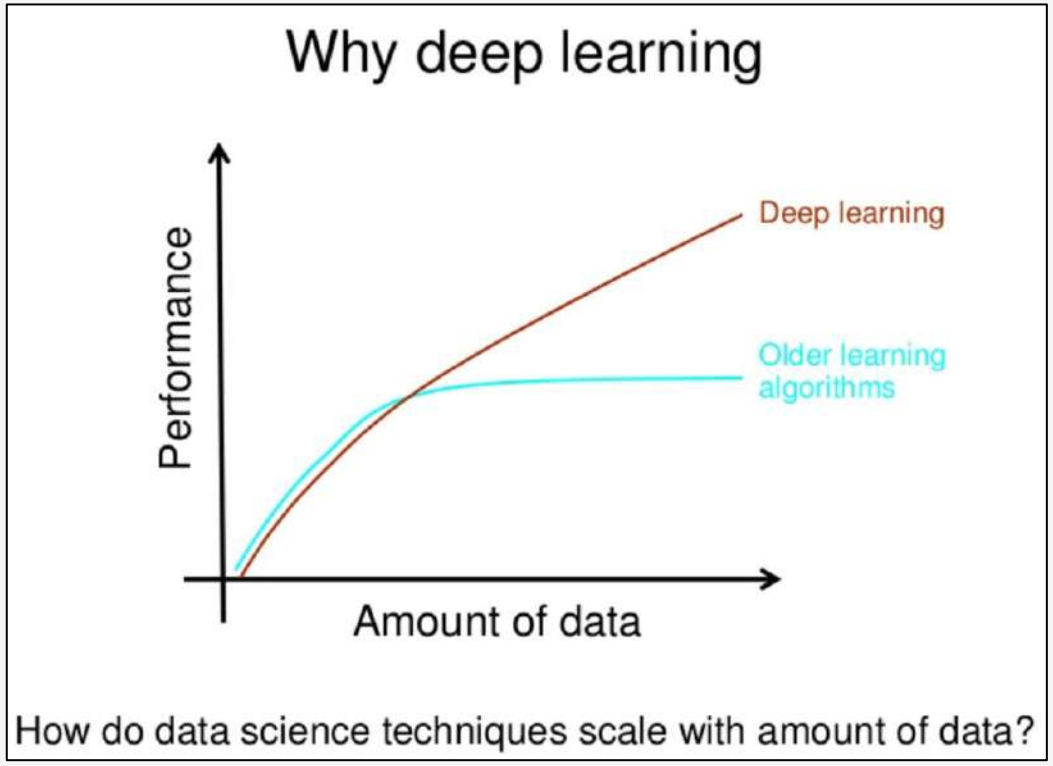


Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

Machine Learning — An Approach to Achieve Artificial Intelligence

Deep Learning — A Technique for Implementing Machine Learning

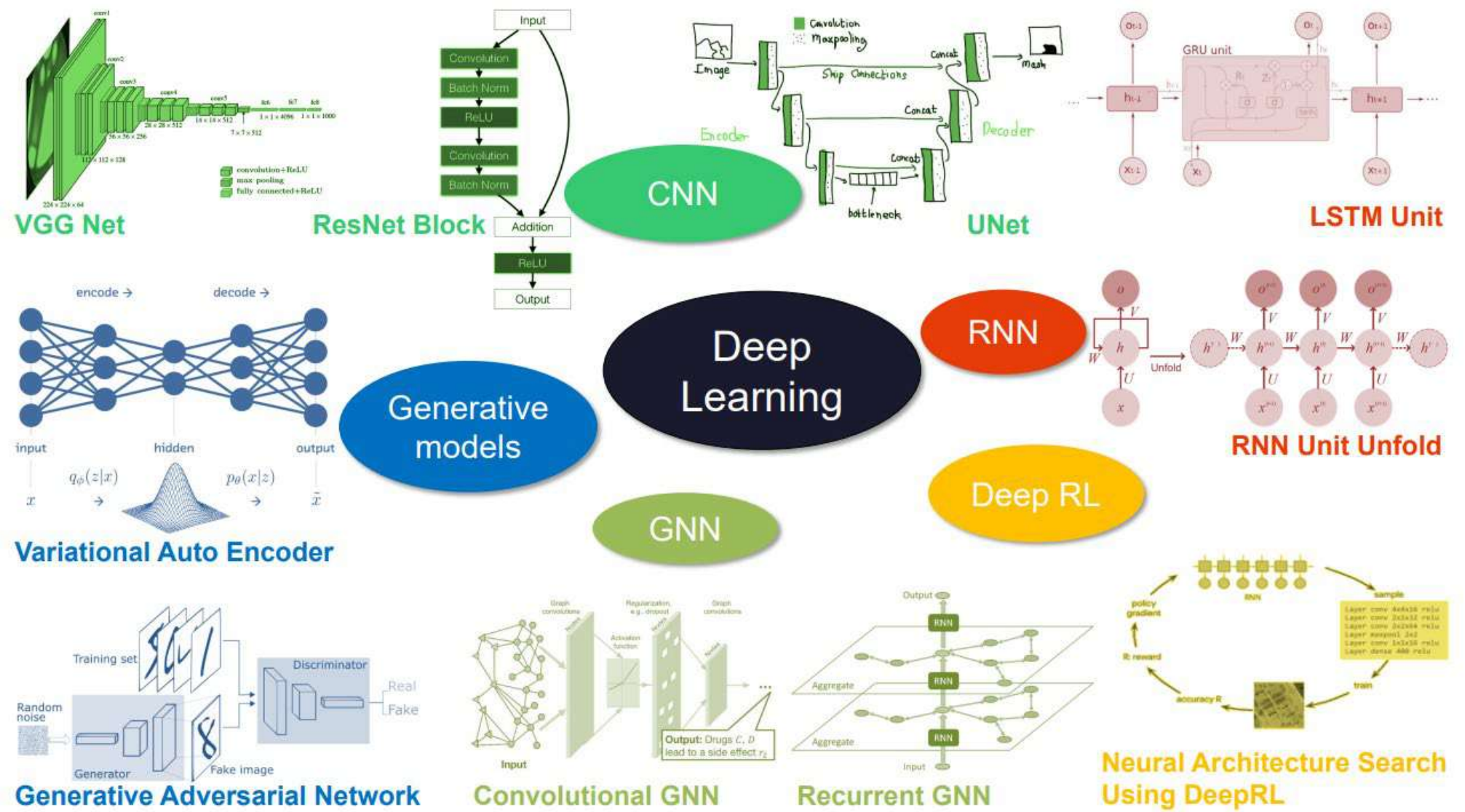
Deep Learning



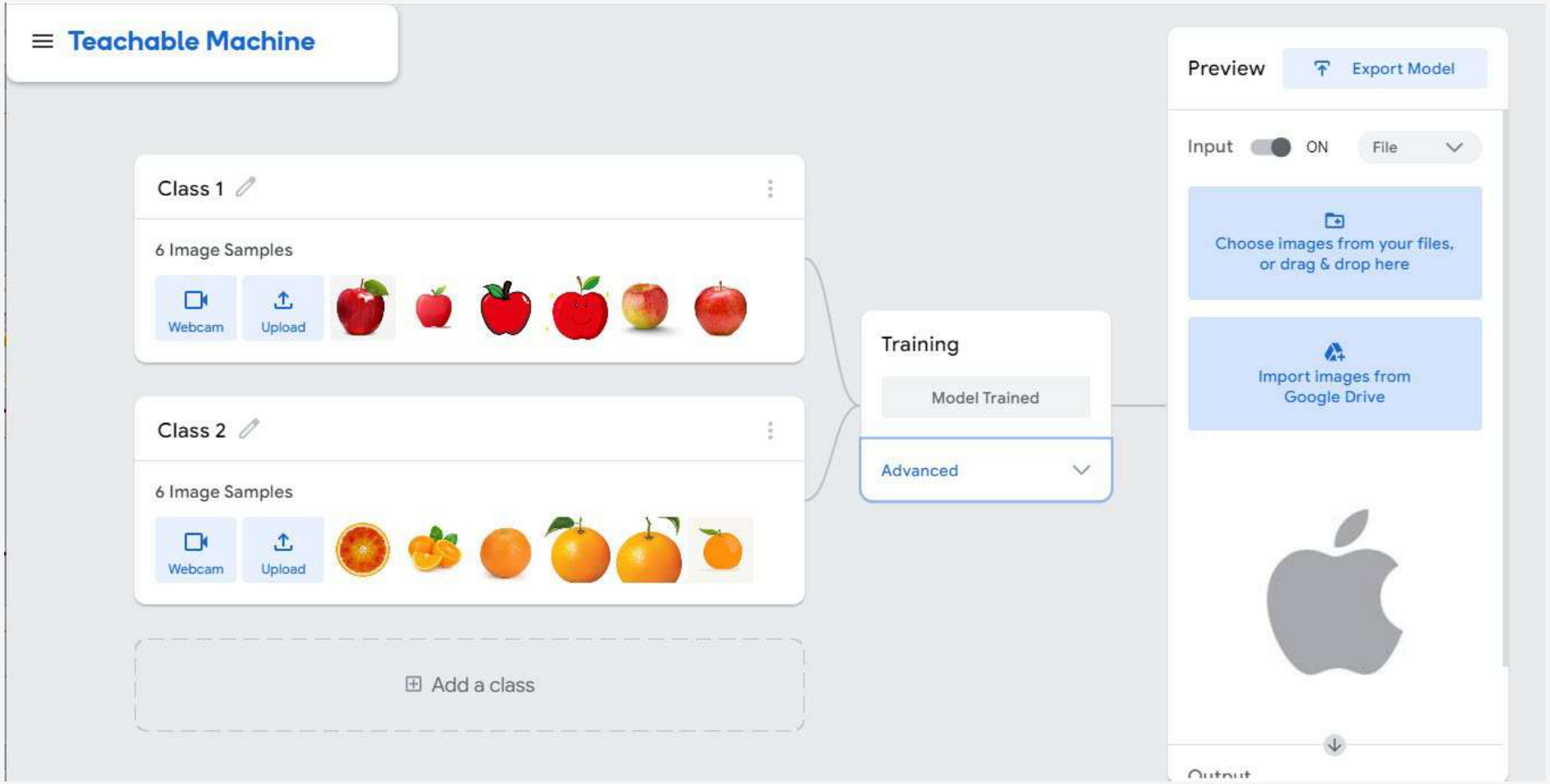
more data + **bigger models** + more computation

Better results

Deep Learning Models

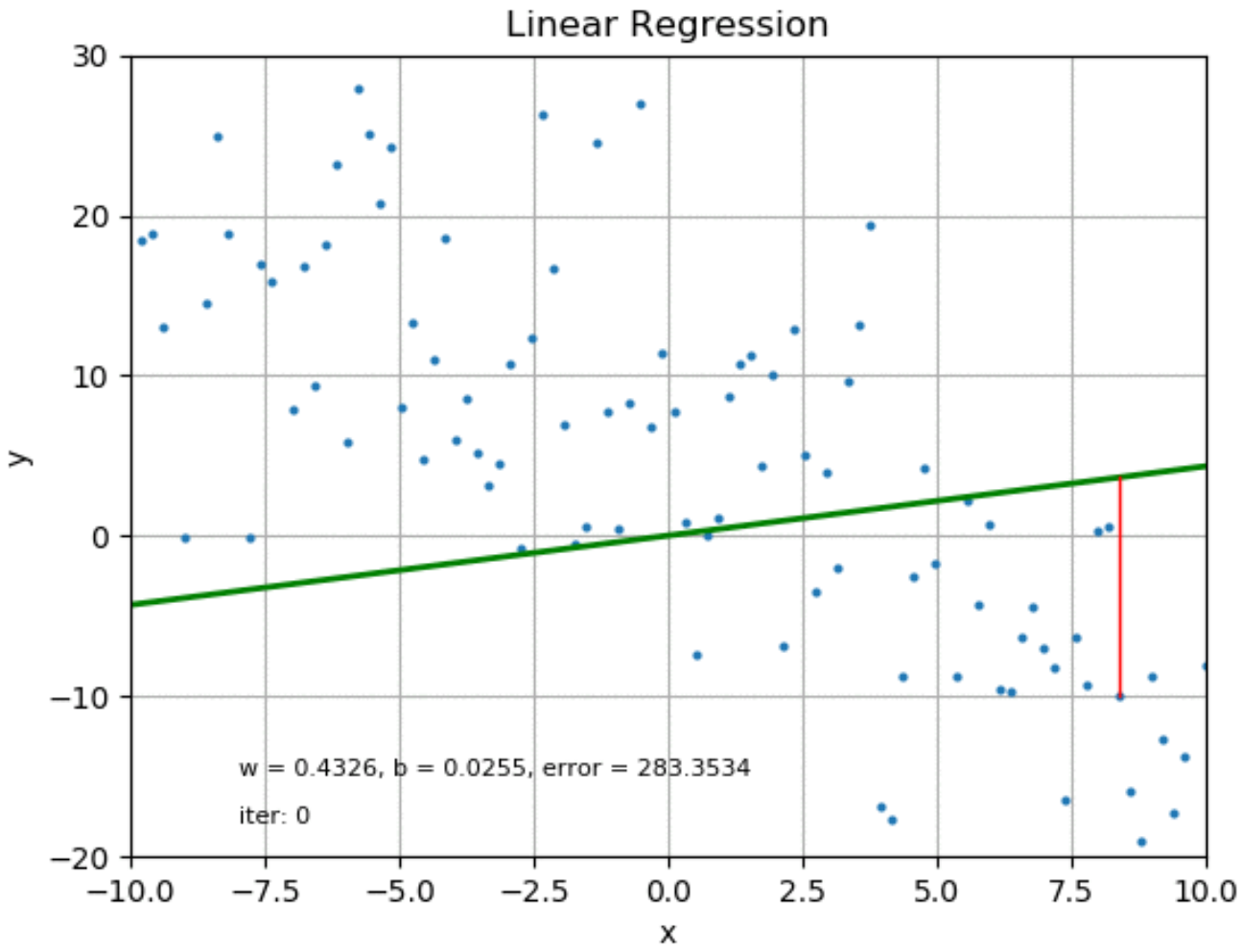


Train A Model: Apple or Orange



https://teachablemachine.withgoogle.com/train/image

Fitting A Line



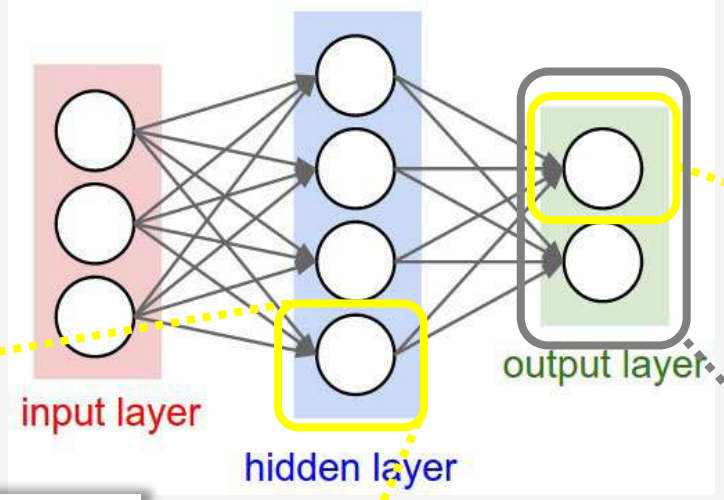
$$y = wx + b$$

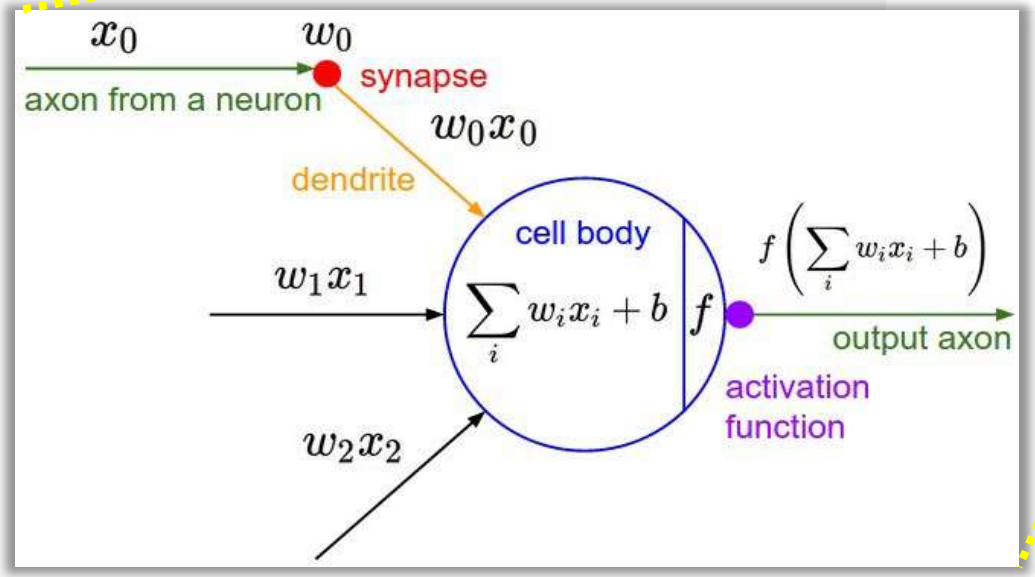
$$\Delta y = wx + b - y_0$$

$$\frac{\partial \Delta y}{\partial b} = b$$

$$\frac{\partial \Delta y}{\partial w} = x$$

Neural Network





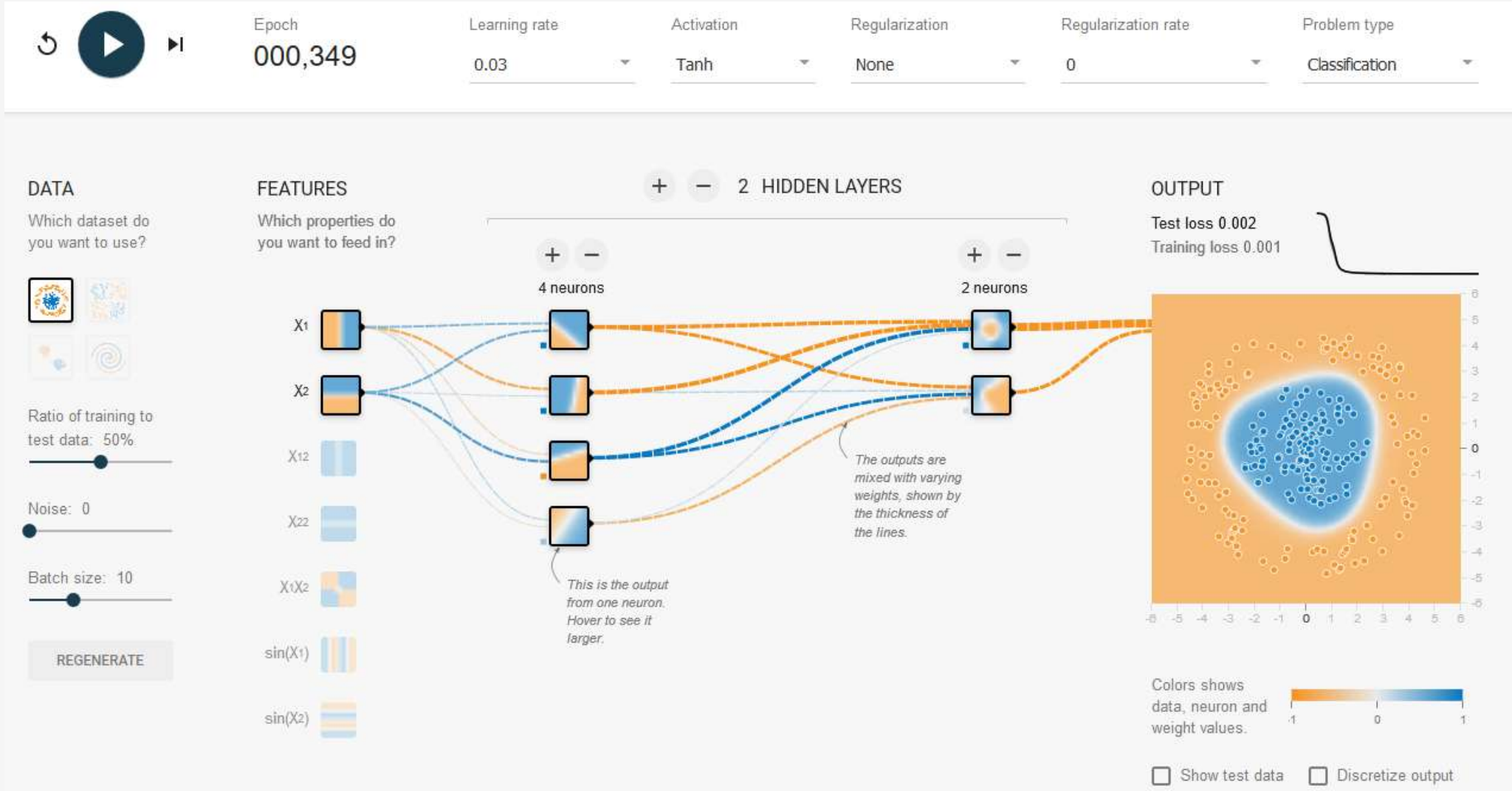
$$p_j = \frac{\exp(h_j/T)}{\sum_i \exp(h_i/T)}$$

Minimising

$$loss = -\sum_i y_i \log(p_i)$$

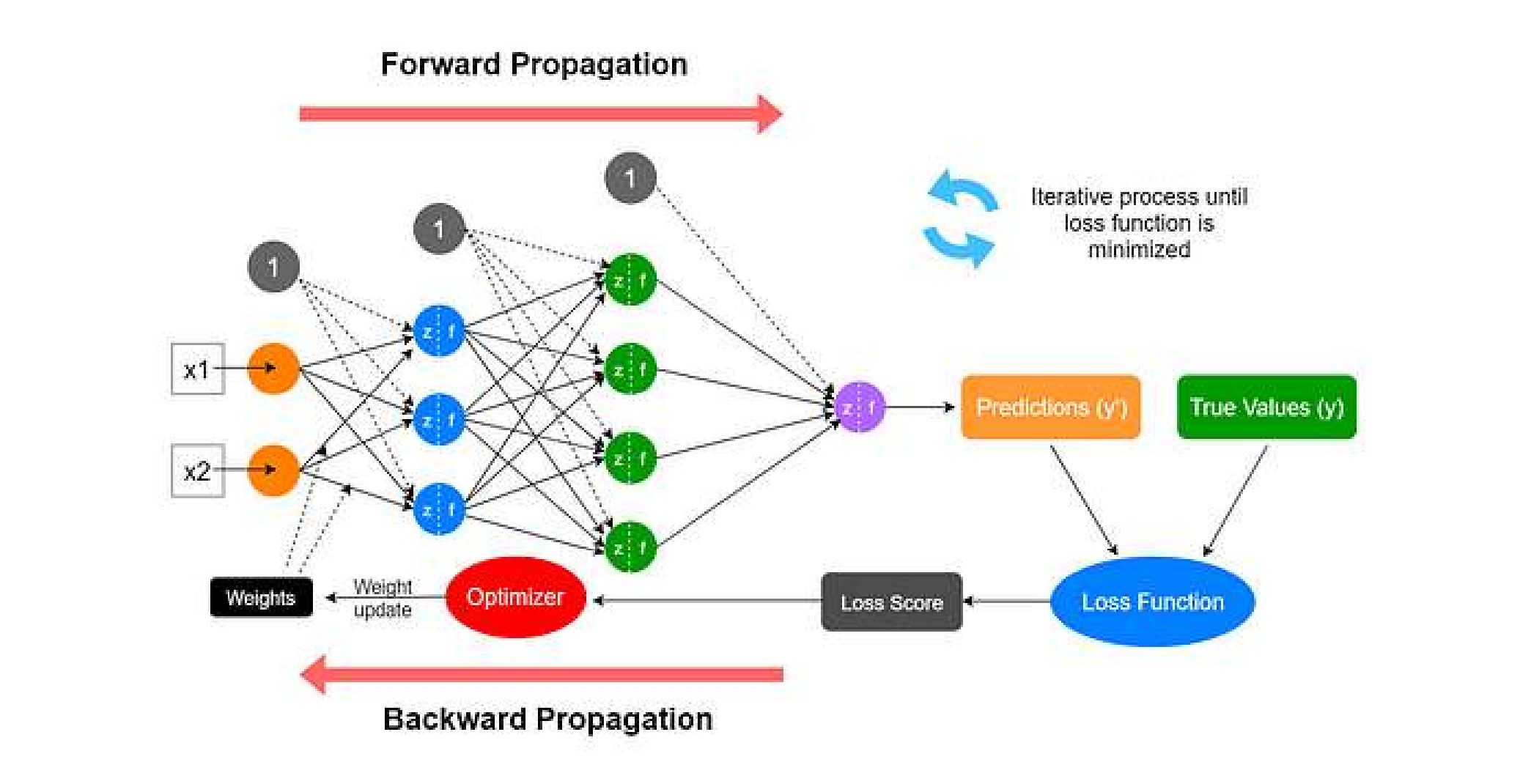
$$h = f\left(\sum_i w_i x_i + b\right)$$

Neural Network



http://playground.tensorflow.org/

Neural Network



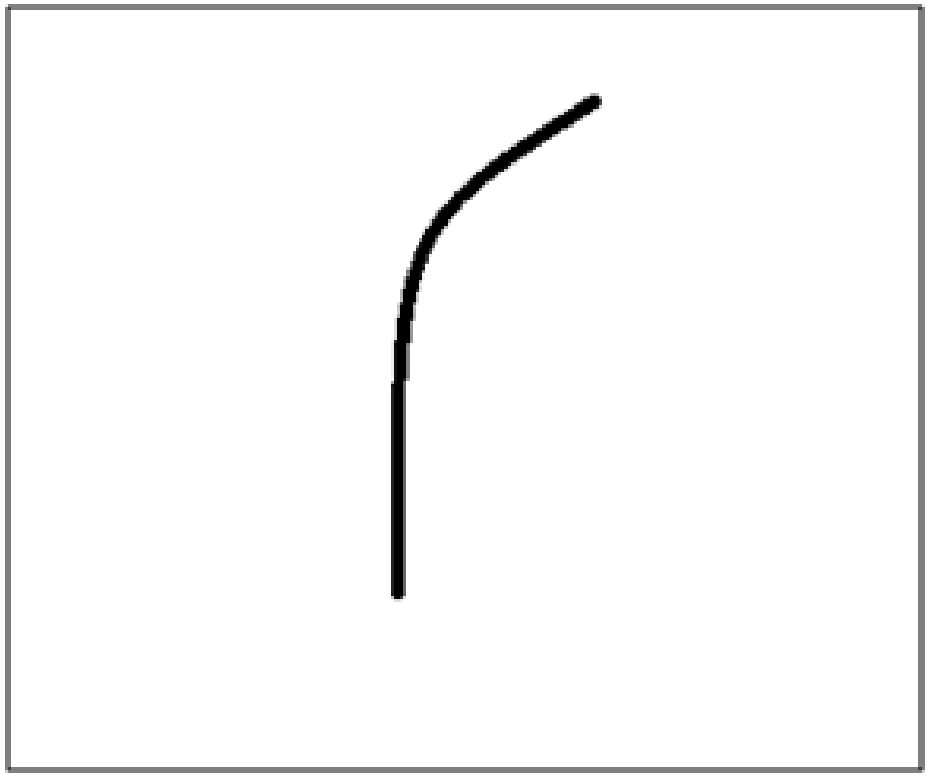
1D -> 2D

Sequential NN → Convolutional NN

Convolutional Neural Network

0	0	0	0	0	30	0
0	0	0	0	30	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	0	0	0	0

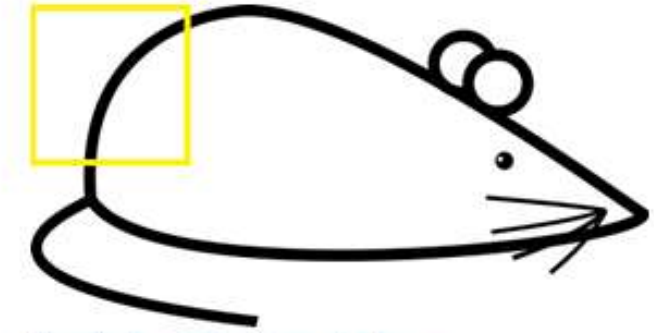
Pixel representation of filter



Visualization of a curve detector filter

Convolutional Neural Network

Original image



Visualization of the filter on the image

Visualization of the receptive field

0	0	0	0	0	0	30
0	0	0	0	50	50	50
0	0	0	20	50	0	0
0	0	0	50	50	0	0
0	0	0	50	50	0	0
0	0	0	50	50	0	0
0	0	0	50	50	0	0

Pixel representation of the receptive field

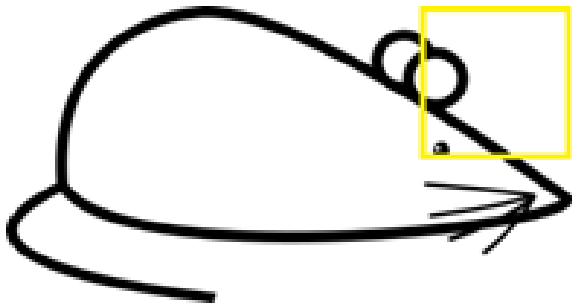
*

0	0	0	0	0	30	0
0	0	0	0	30	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	0	0	0	0

Pixel representation of filter

Multiplication and Summation = (50*30)+(50*30)+(50*30)+(20*30)+(50*30) = 6600 (A large number!)

Convolutional Neural Network



Visualization of the filter on the image

0	0	0	0	0	0	0
0	40	0	0	0	0	0
40	0	40	0	0	0	0
40	20	0	0	0	0	0
0	50	0	0	0	0	0
0	0	50	0	0	0	0
25	25	0	50	0	0	0

Pixel representation of receptive field

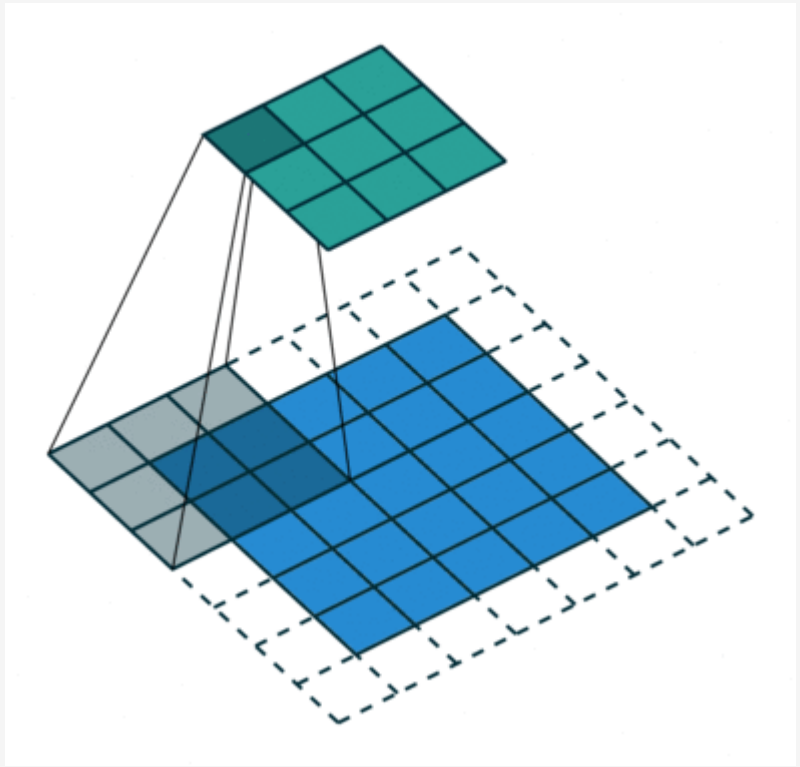
*

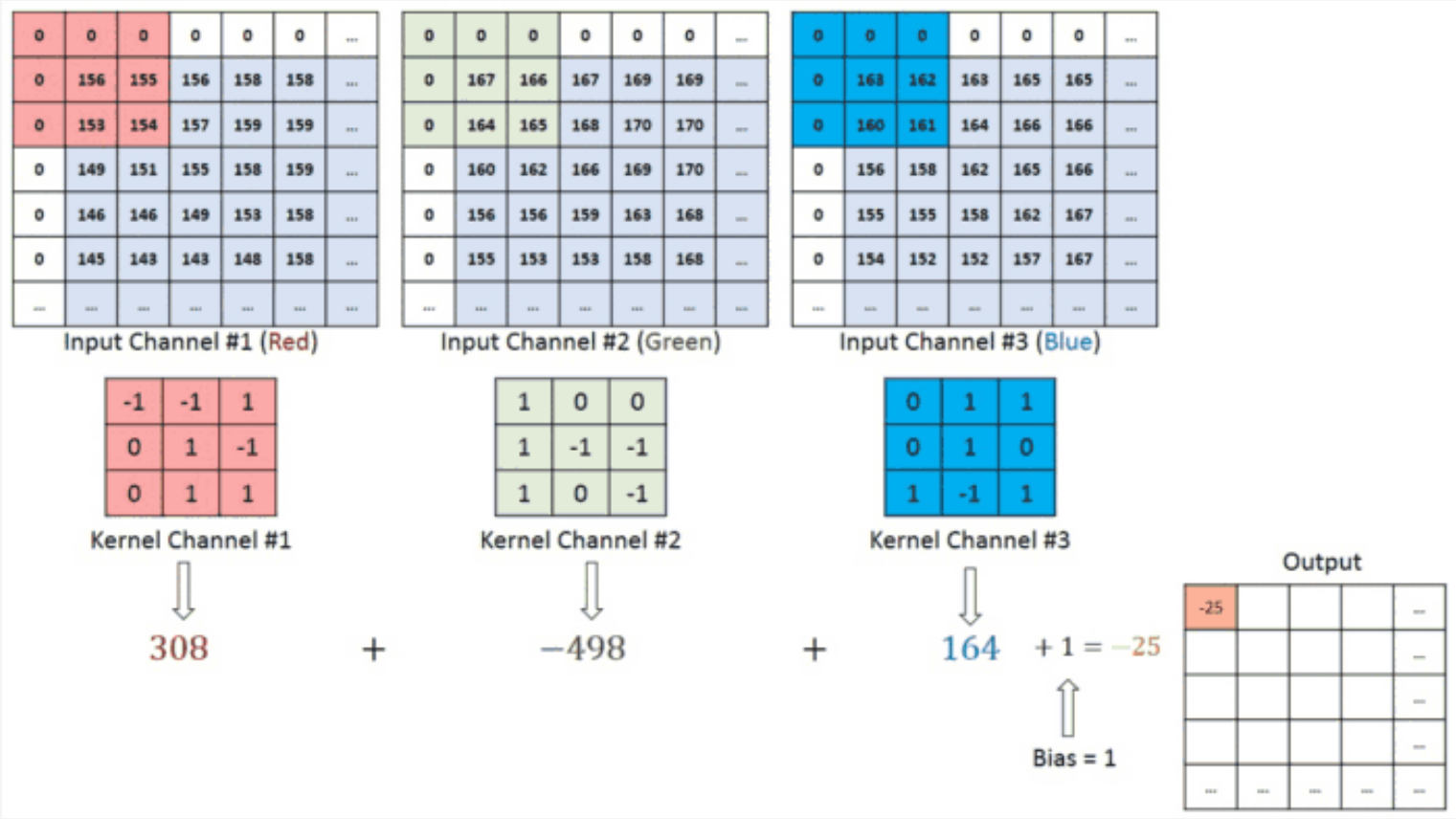
0	0	0	0	0	30	0
0	0	0	0	30	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	0	0	0	0

Pixel representation of filter

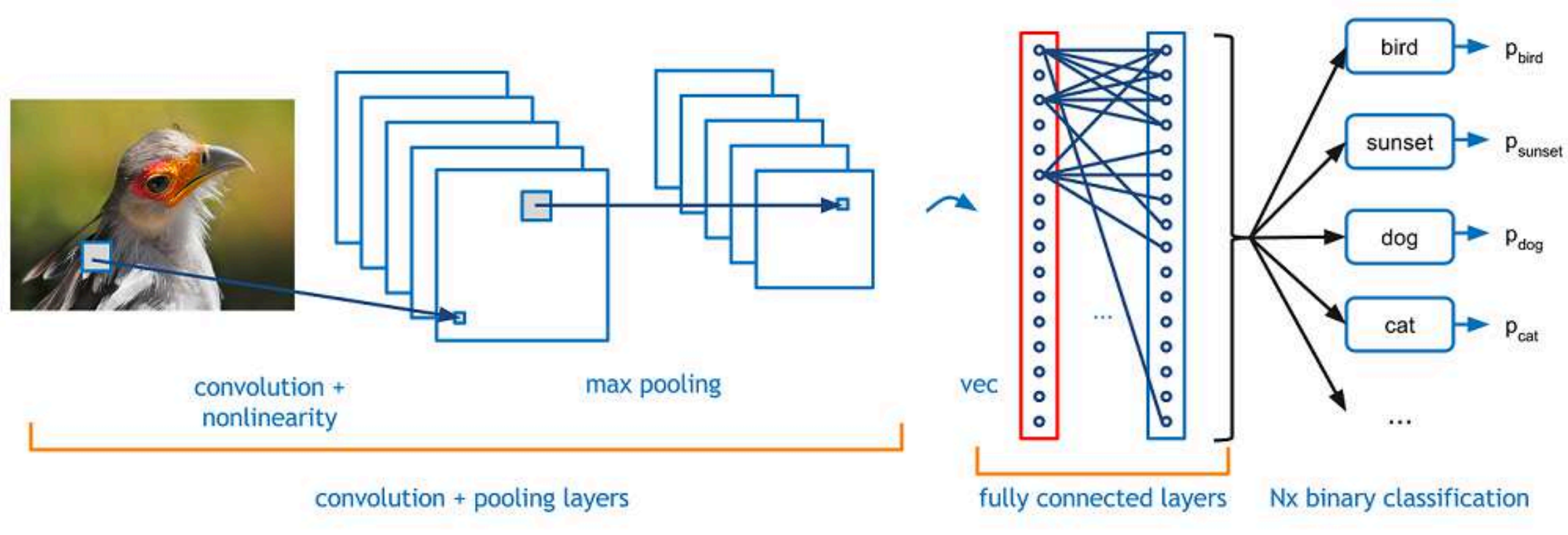
Multiplication and Summation = 0

Convolutional Neural Network



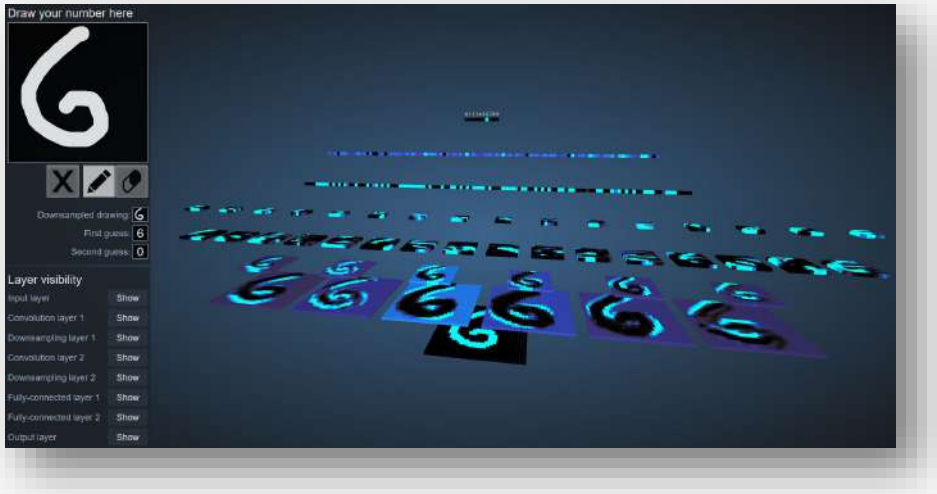


Convolutional Neural Network



Visualization of CNN

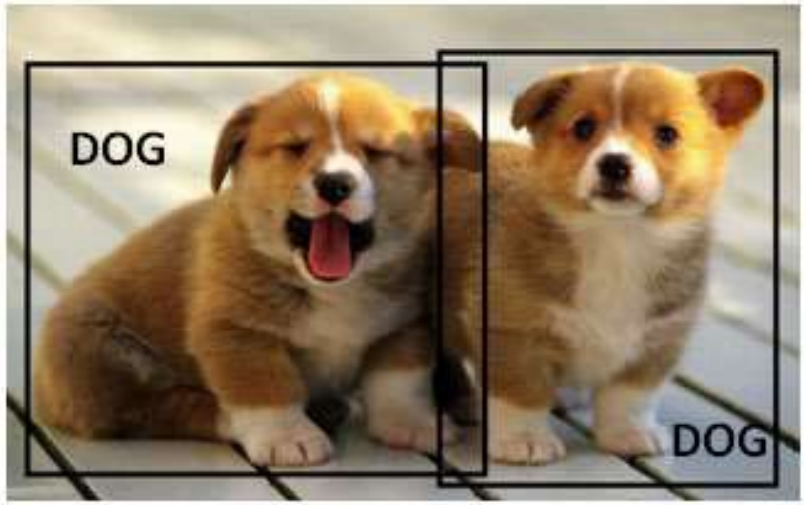
https://poloclub.github.io/cnn-explainer/



https://adamharley.com/nn_vis/cnn/3d.html

Classification, Object Detection, Segmentation

Object Classification is the task of identifying that picture is a dog



Object Detection involves localization of multiple objects (doesn't have to be the same class).

Object Segmentation involves the class label as well as an outline of the object in interest.

Types of Machine Learning

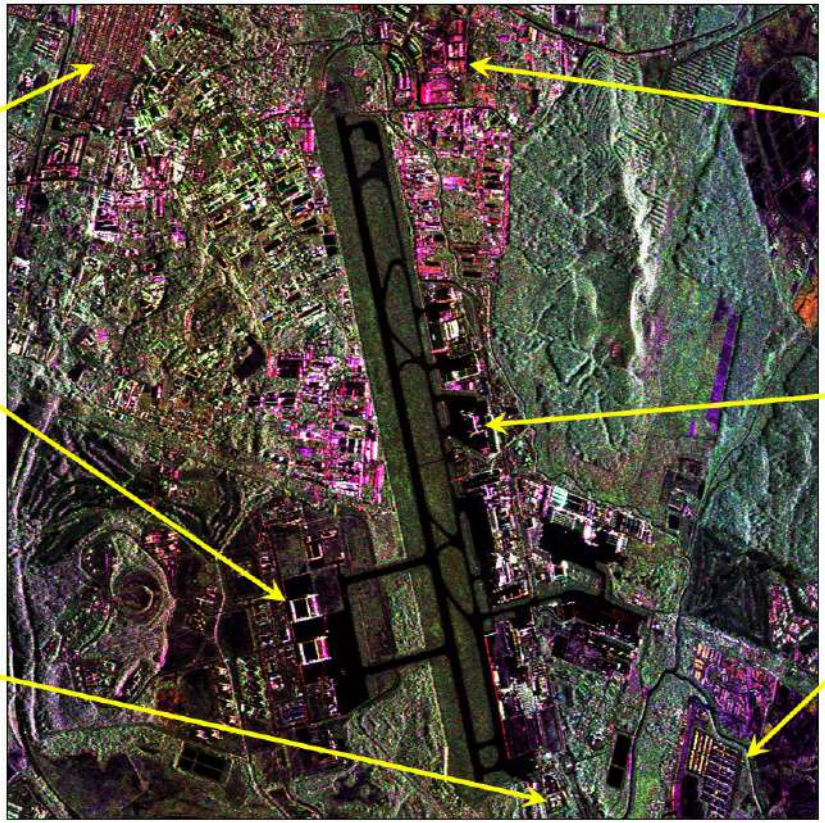
		Definitions	Algorithms
Supervised learning	Classification (discrete, class labels)	Identifying to which category an object belongs to.	SVM, nearest neighbors, random forest
	Regression (continuous, number)	Predicting a continuous-valued attribute associated with an object.	SVR, ridge regression, Lasso
Unsupervised learning	Clustering	Automatic grouping of similar objects into sets.	k-Means, spectral clustering
	Dimensionality reduction	Reducing the number of random variables to consider.	PCA, feature selection, non-negative matrix factorization

Landcover Classification (SAR)


Residential estate


Hangars

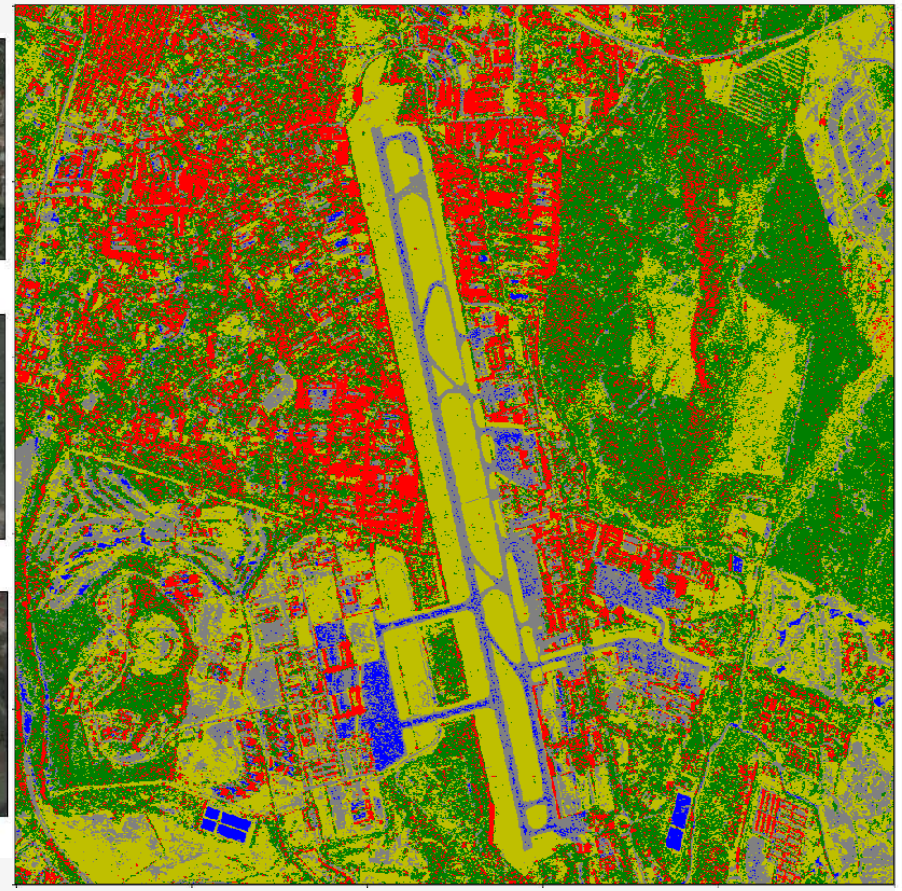

Fuel depot



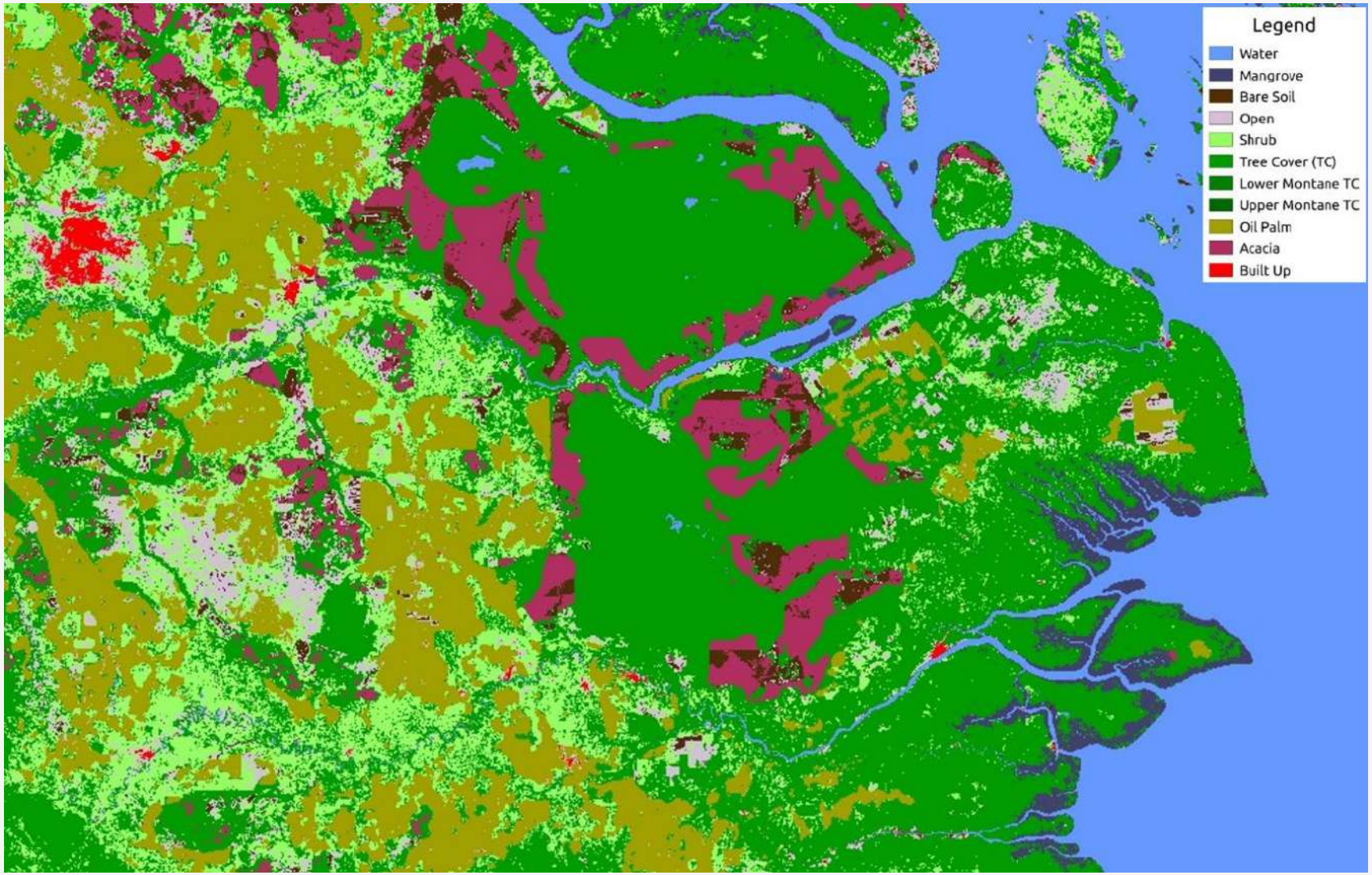

Residential flats


Terminal


Light industrial buildings



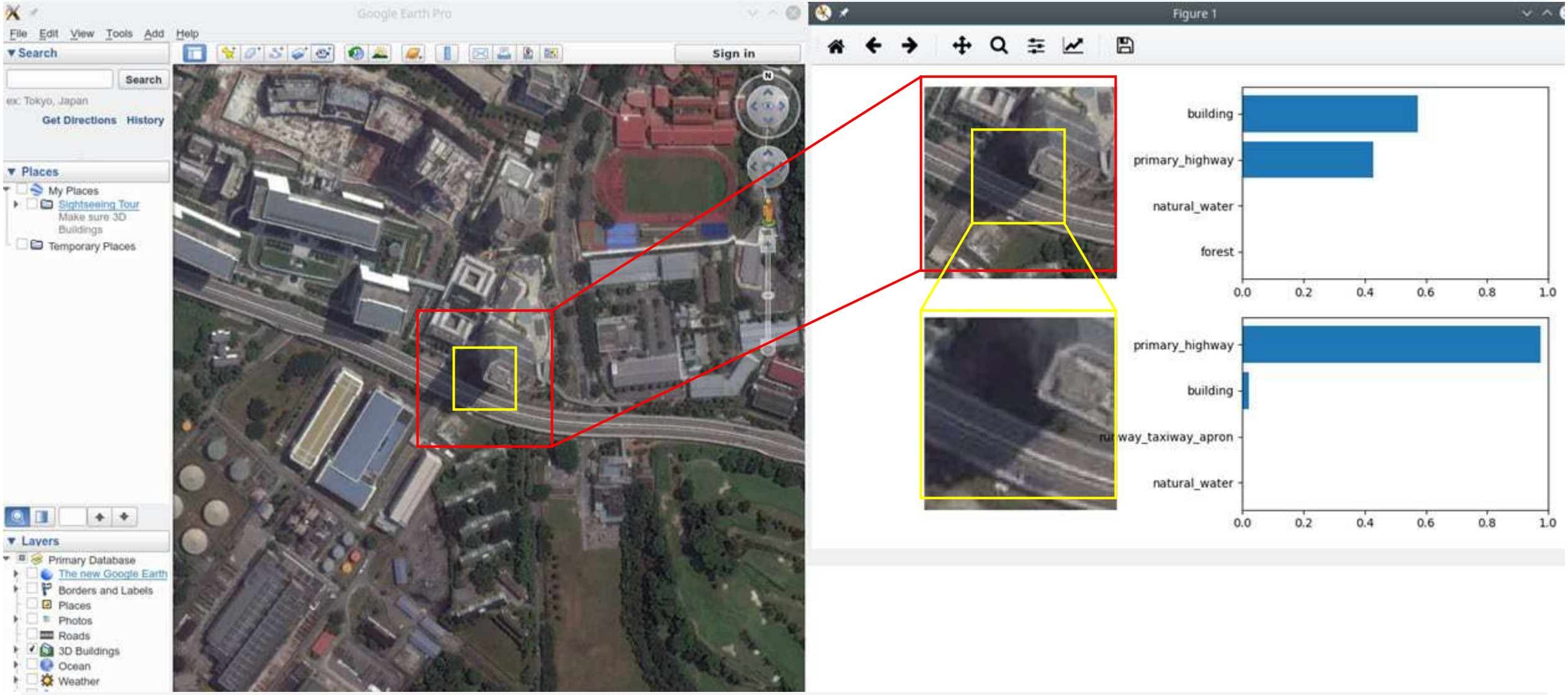
Landcover Classification (SAR+Optical)



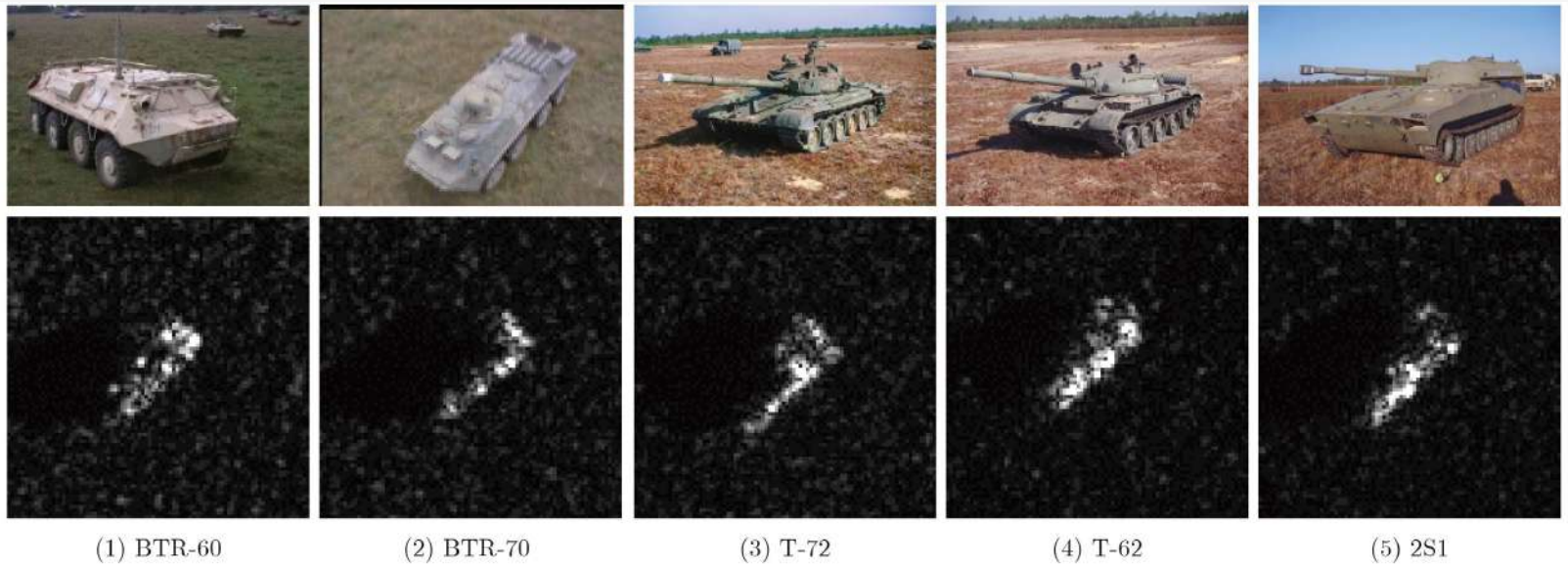
2021 CRISP land cover map over Riau, Sumatra

Land Use Classification

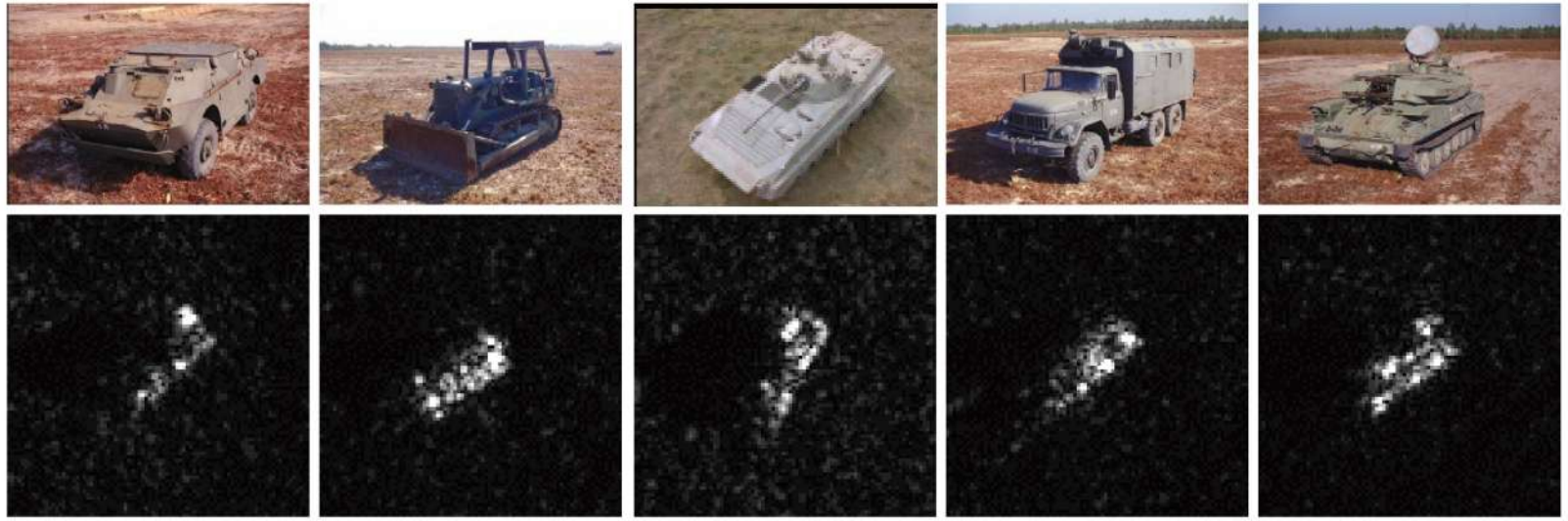
Land Use Classification



SAR Target Classification

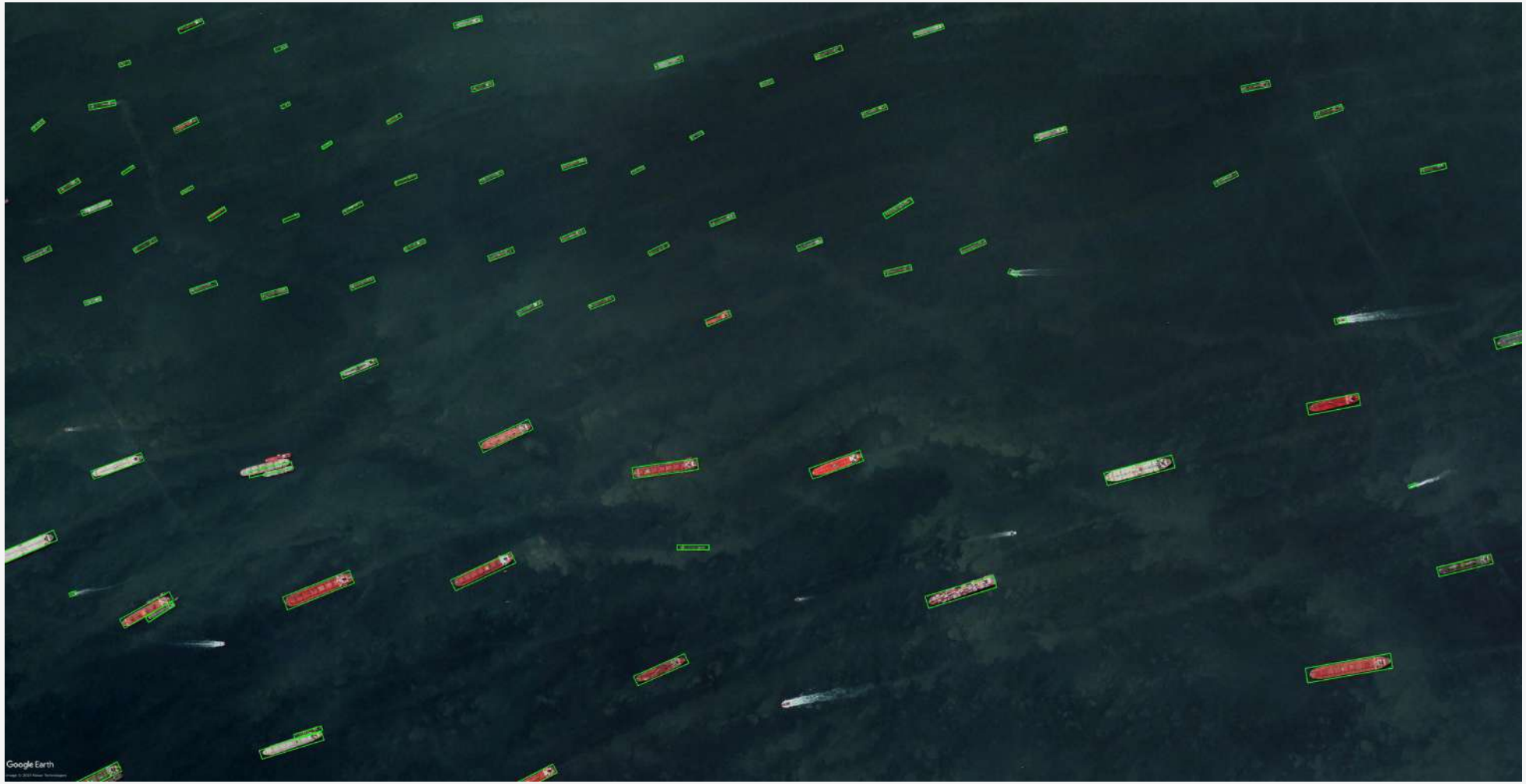


(1) BTR-60 (2) BTR-70 (3) T-72 (4) T-62 (5) 2S1

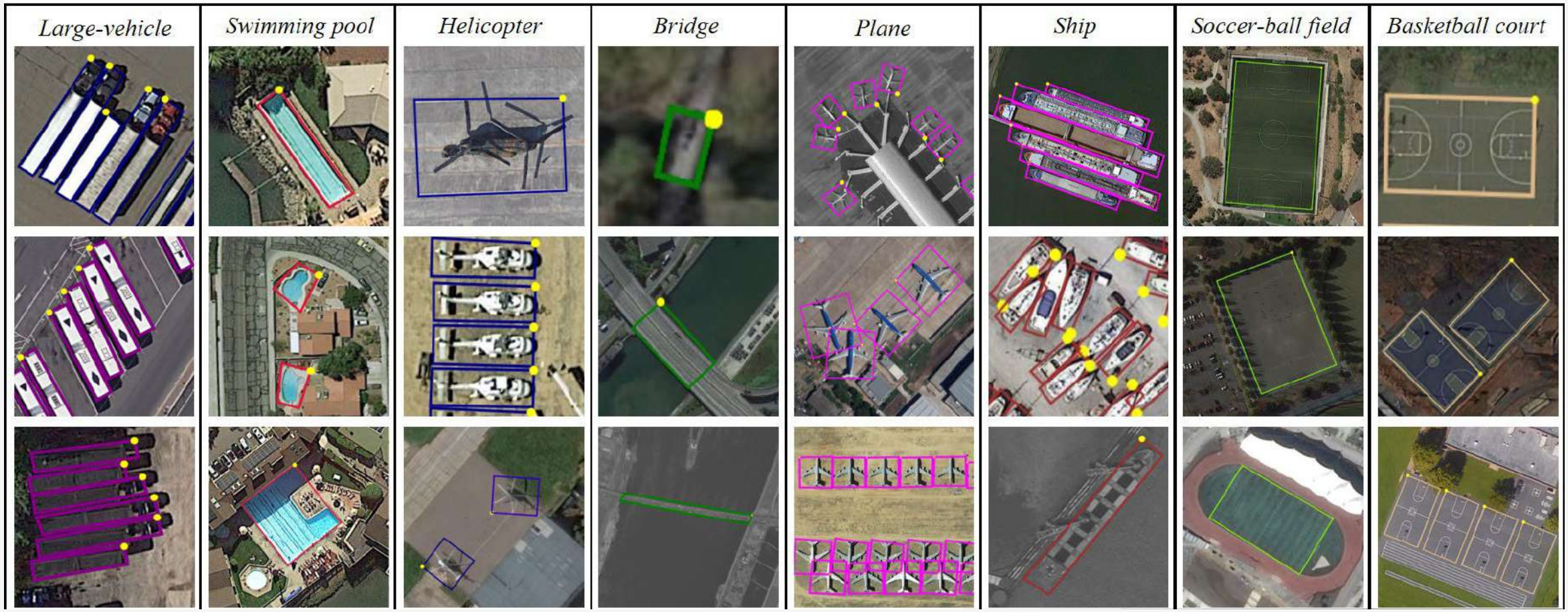


(6) BRDM-2 (7) D7 (8) BMP-2 (9) ZIL-131 (10) ZSU-234

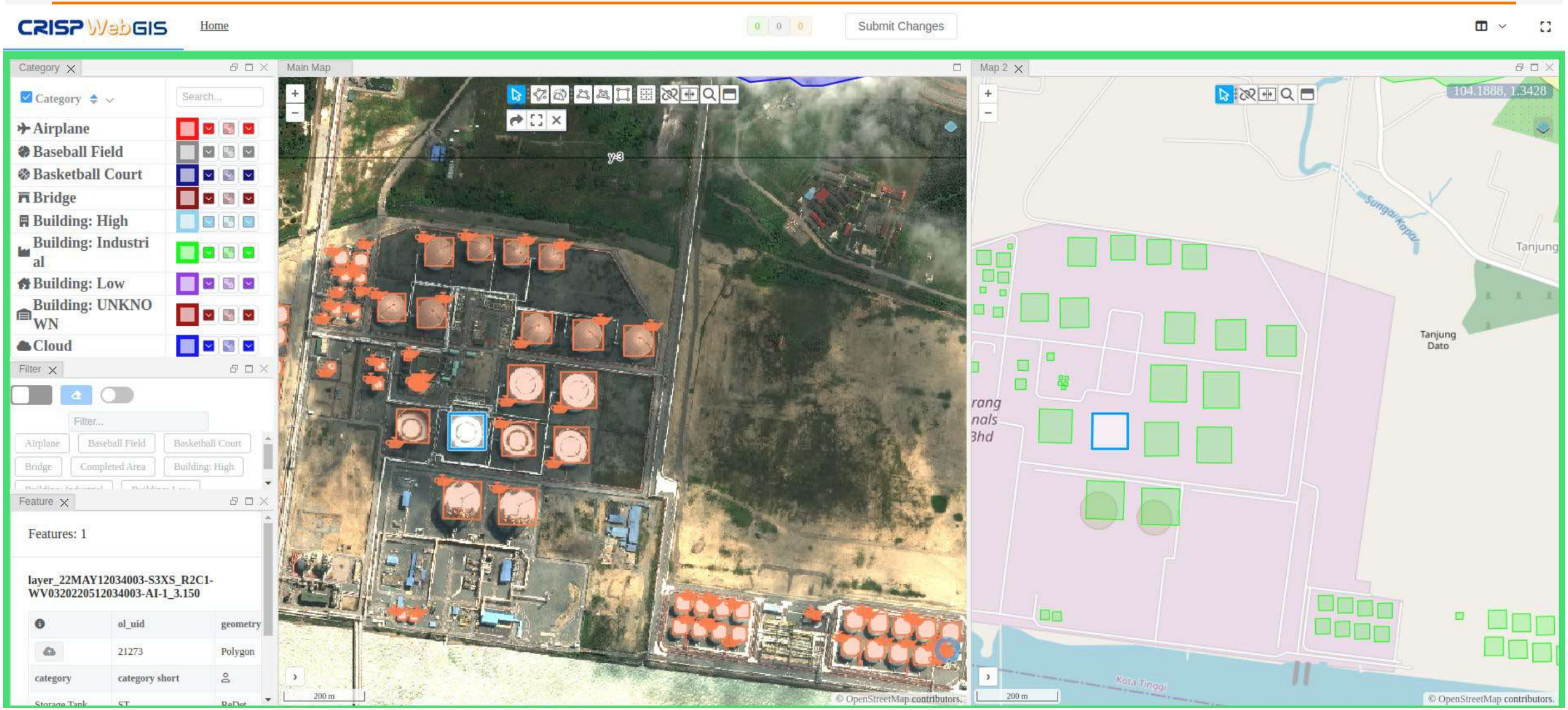
Ship Detection



Object Detection



Object Detection



Building Segmentation

Machine Learning in GEE

- **Supervised Classification:**
  - Use examples to teach a model to differentiate between classes.

- **Unsupervised Classification:**
  - No examples given. Instead, the algorithm divides the available data into clusters based on inherent differences.

- **Regression:**
  - To predict a continuous variable for each input. For example, predict water quality, percent forest cover, percent cloud cover or crop yield.

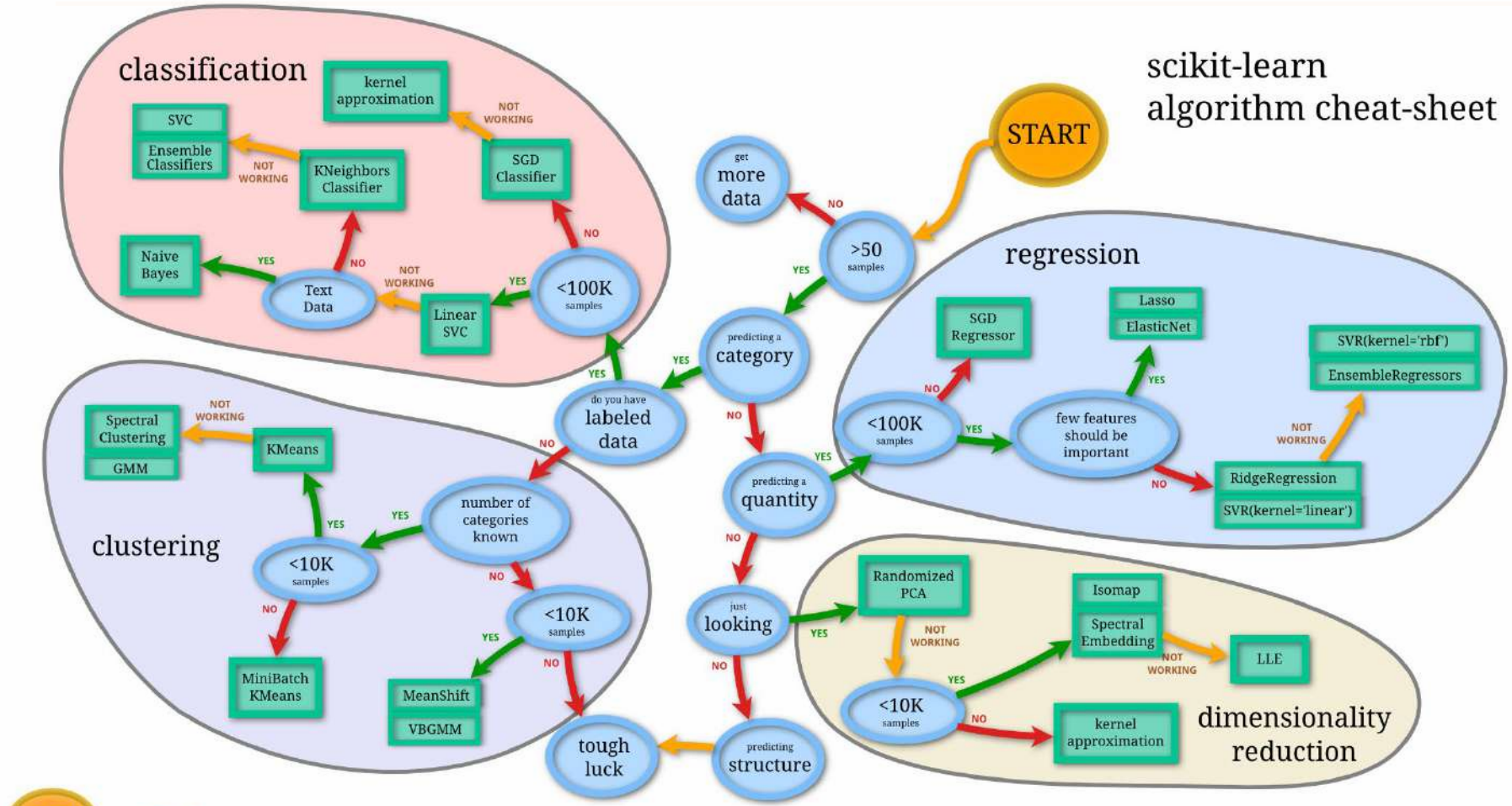
Machine Learning in GEE

- **Supervised Classification:**
  - ee.Classifier

- **Unsupervised Classification:**
  - ee.Clustere

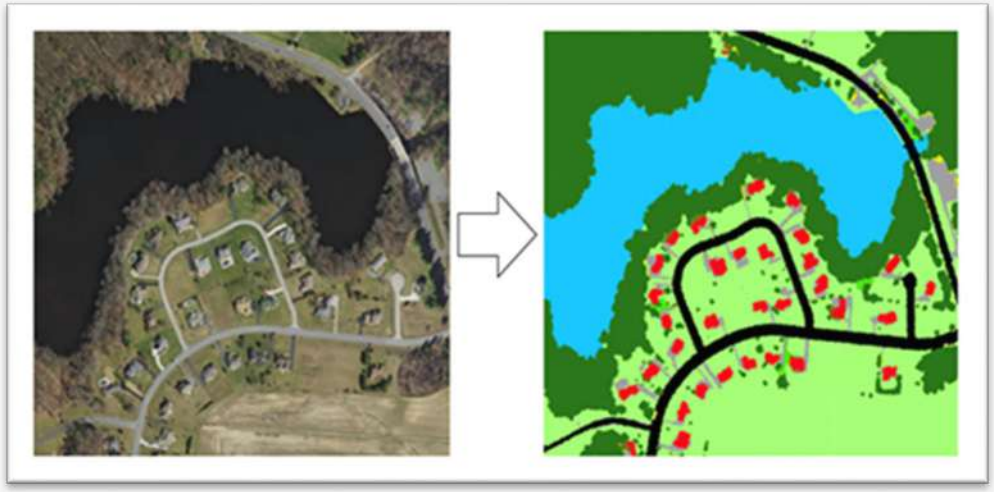
- **Regression:**
  - linear regression using reducers:
  - ee.Reducer.linearFit()
  - ee.Reducer.linearRegression()
  - ee.Reducer.robustLinearRegression()
  - ee.Reducer.ridgeRegression()

Classical Machine Learning Methods

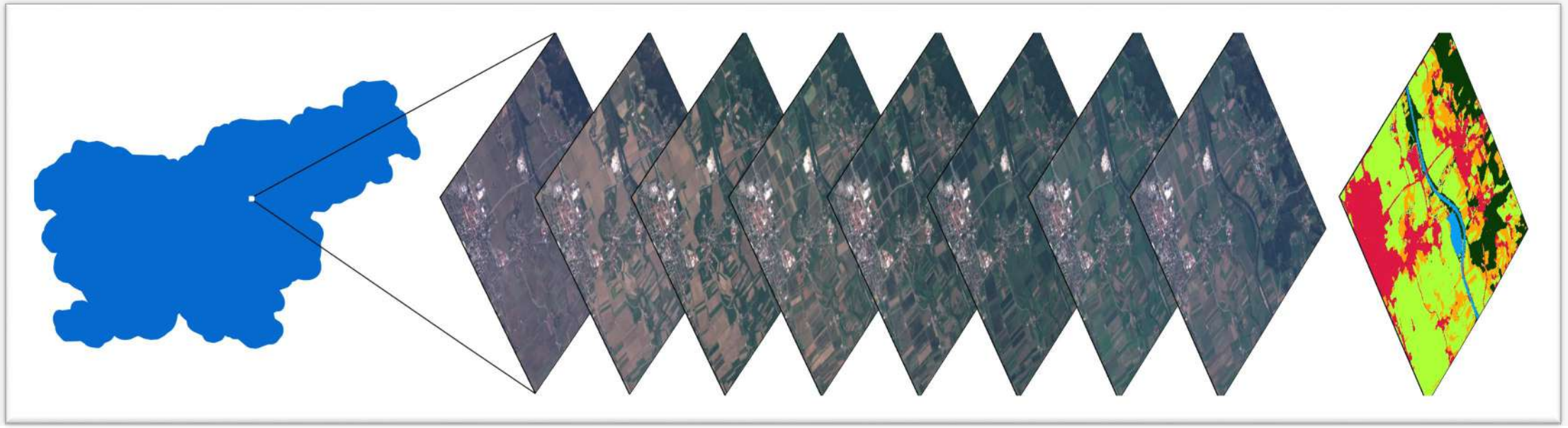


https://scikit-learn.org/stable/tutorial/machine_learning_map/index.html

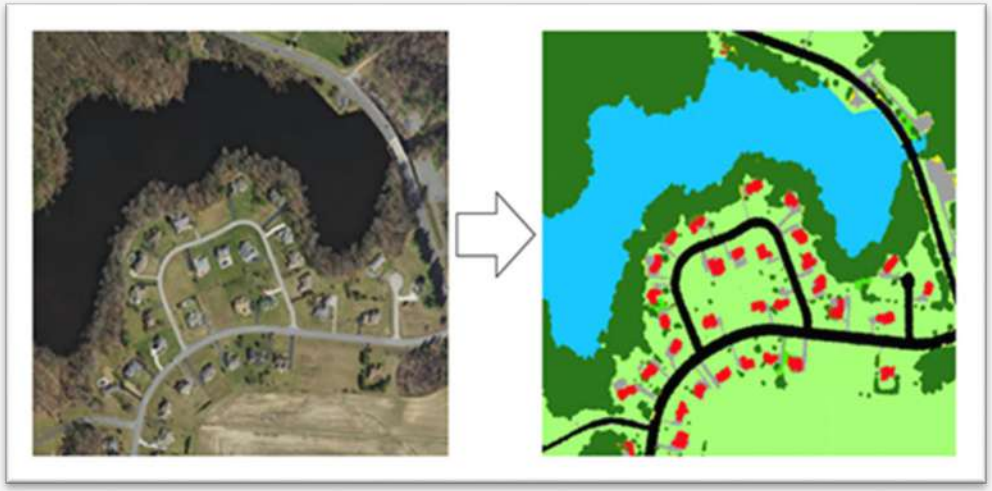
Pixel-based Classification



Single Image
or
Multiple Images



Feature Selection

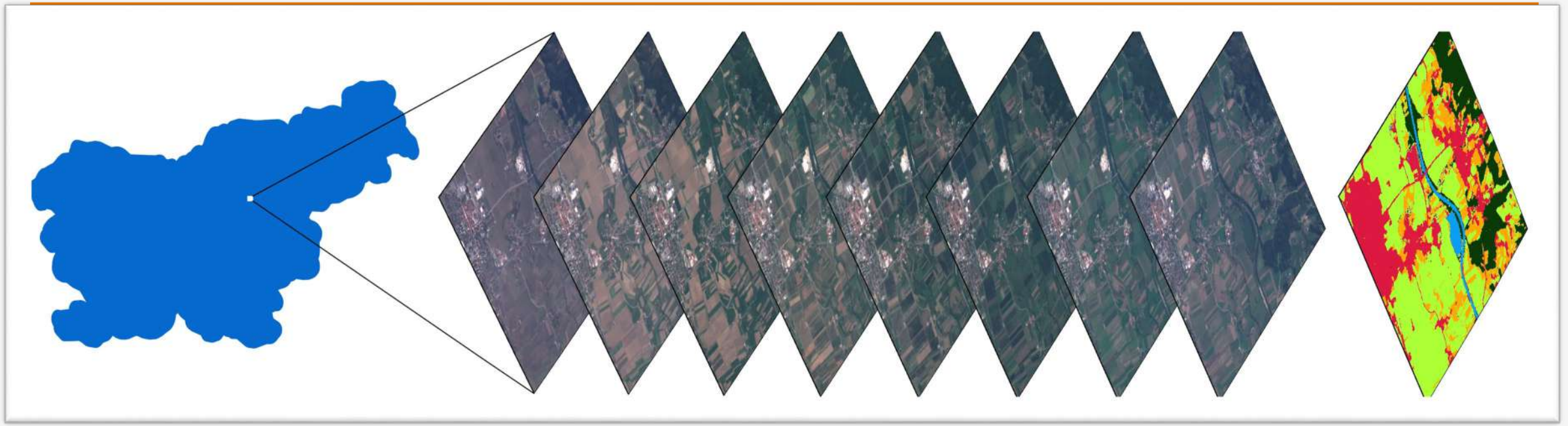


R G B

Three Bands

1 … 5

Labels



R … R

1 … 5

R G B … R G B

Thanks !