

# Introduction to Machine Learning in Remote Sensing

Hou Chen Guang

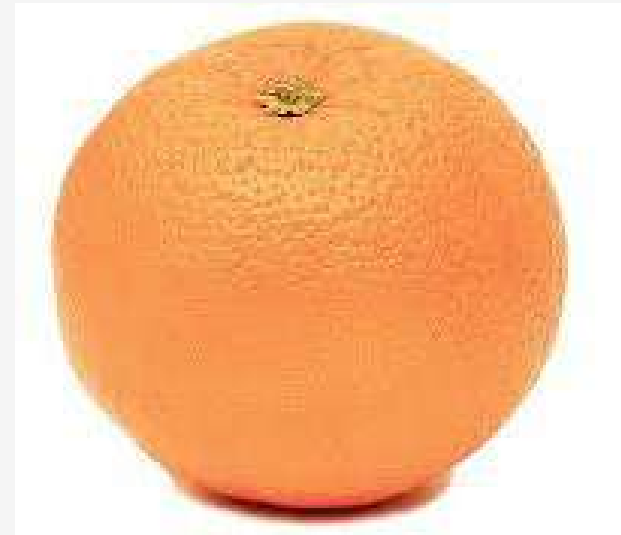
# Contents

---

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

# Apple or Orange

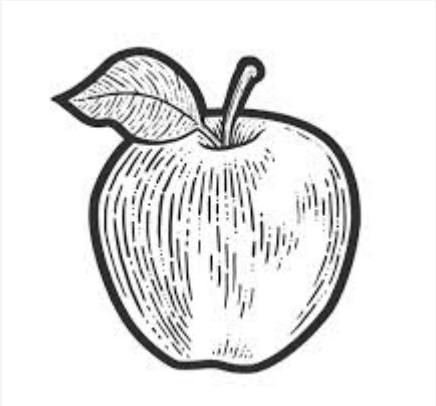
---



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

# Apple or Orange

---



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



# Apple or Orange

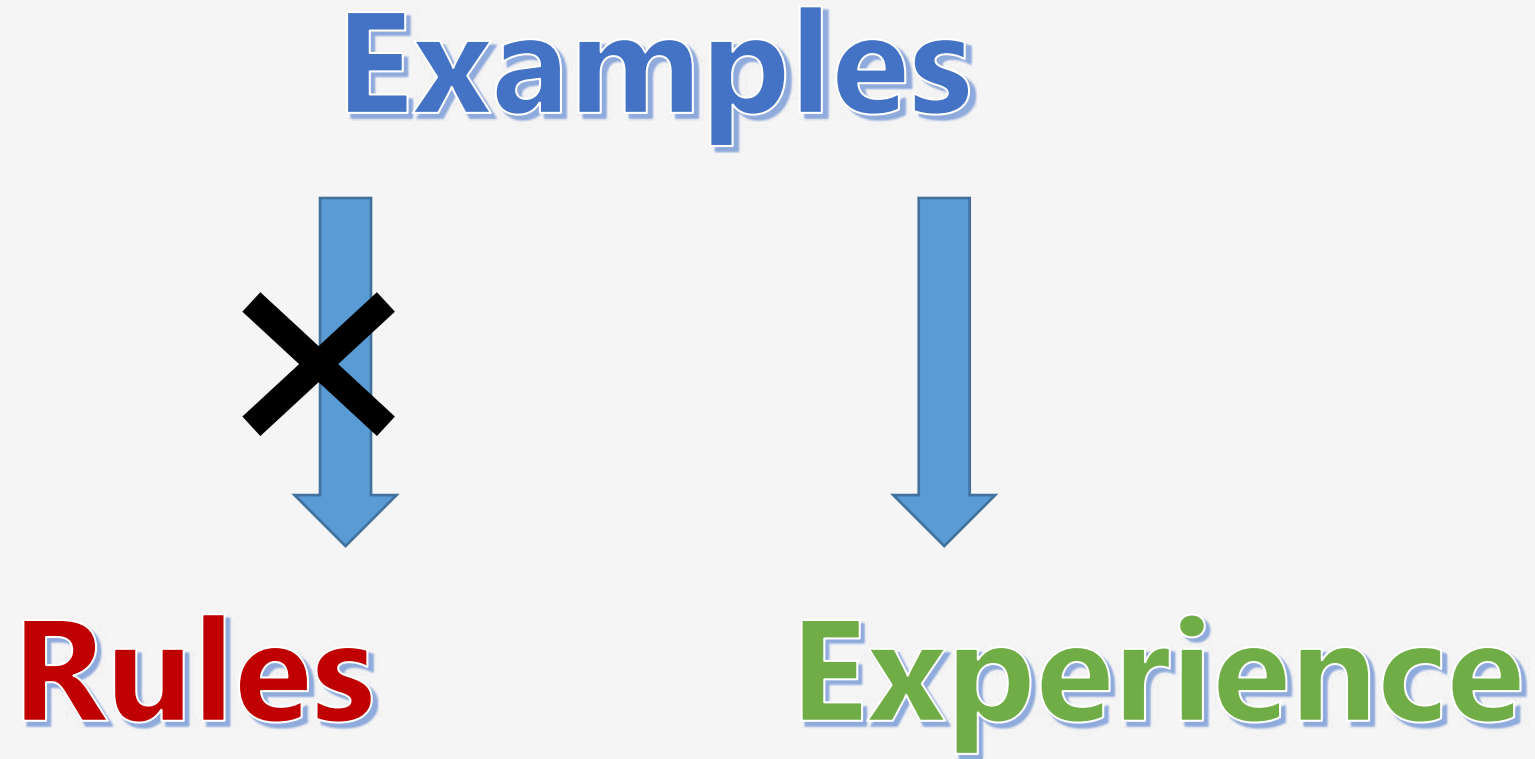
---



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

# Apple or Orange

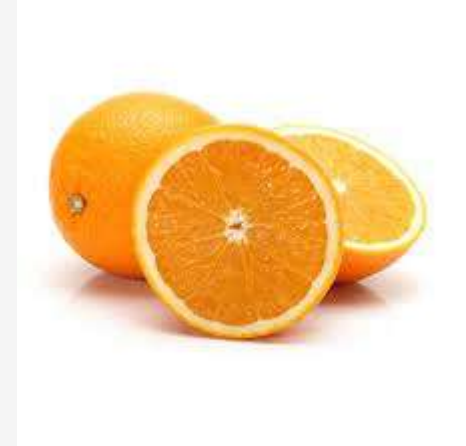
---



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



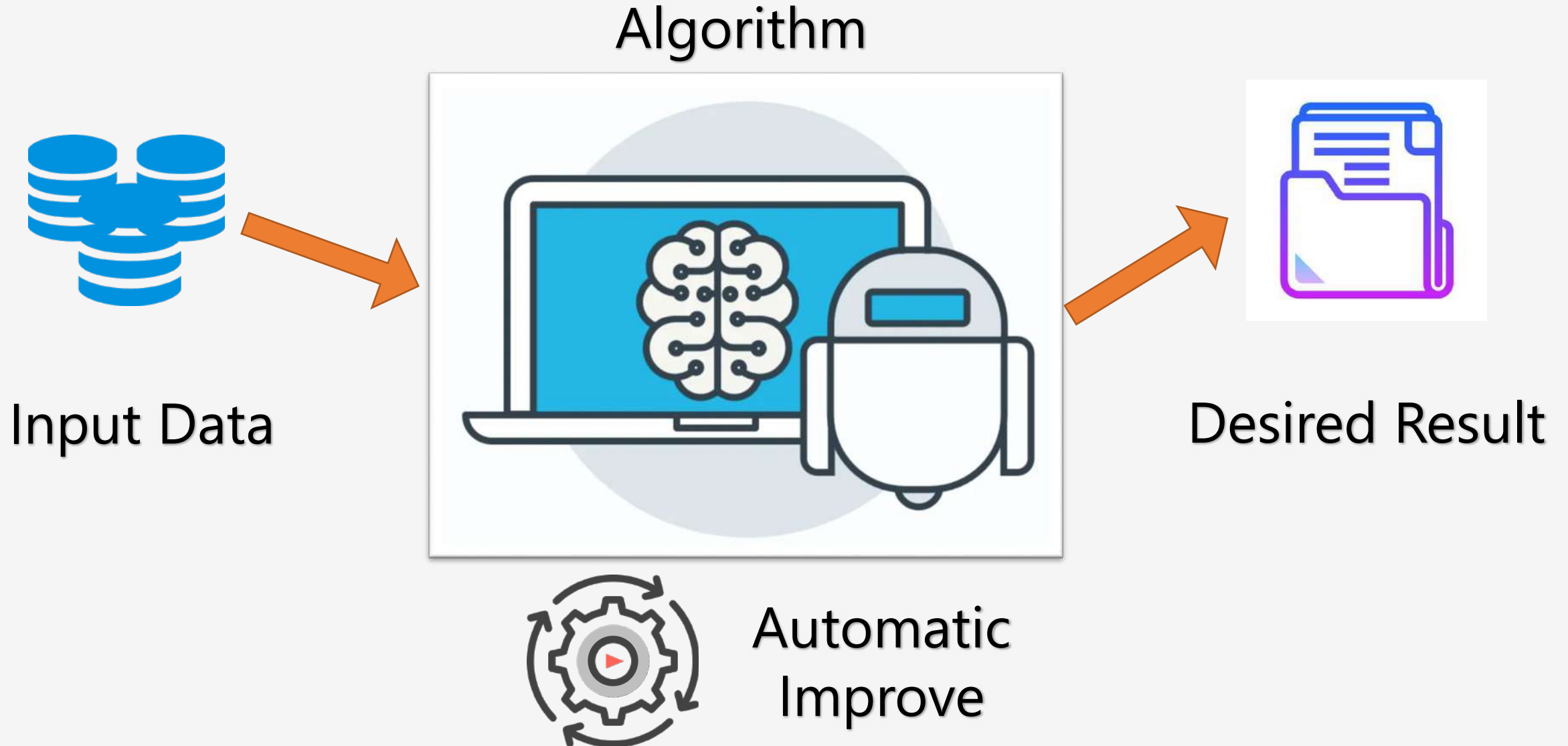
# Apple or Orange



Use the *instincts*



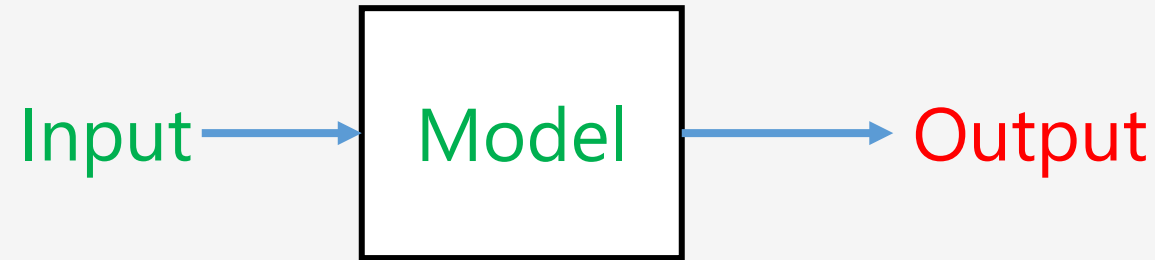
# Introduction to Machine Learning



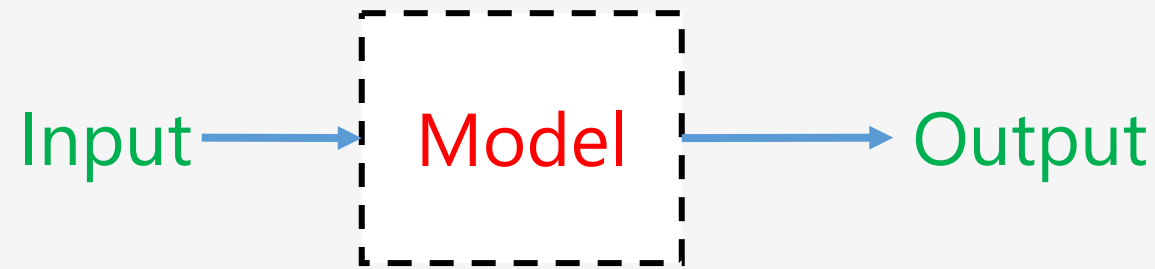
# Machine Learning vs. Classical Approach

■ Given  
■ Wanted

Classical Approach

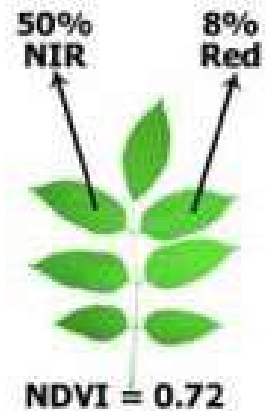


Machine Learning

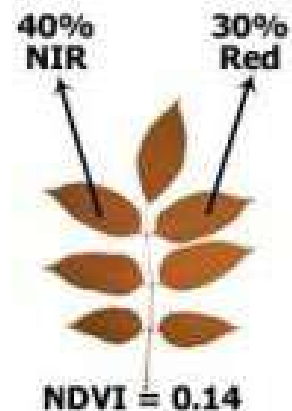


# Classical Approach: NDVI

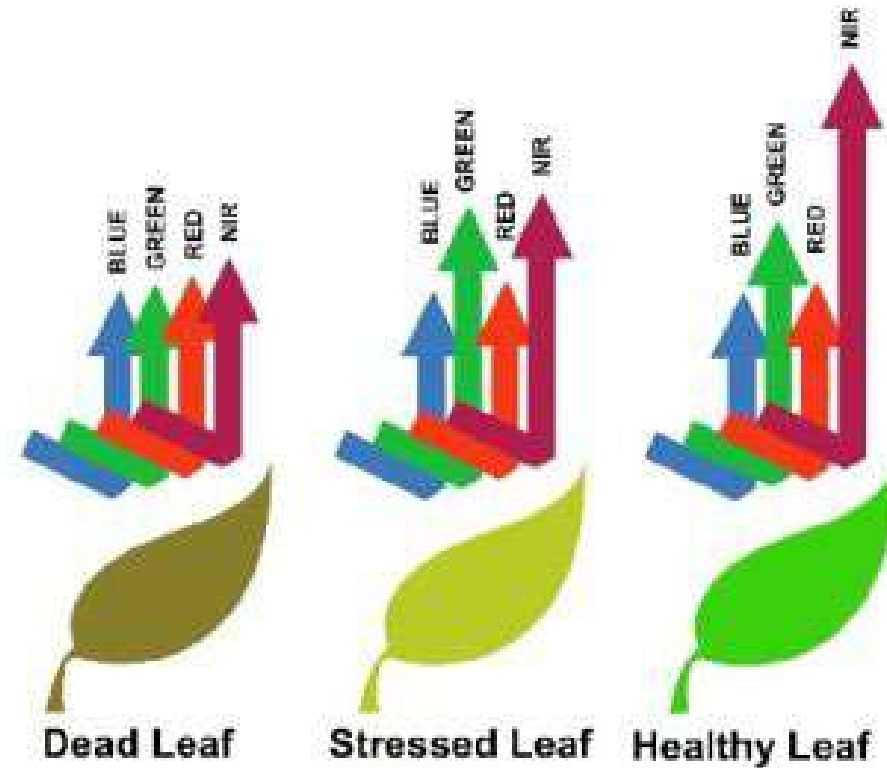
**Heathy Vegetation  
Reflectance**



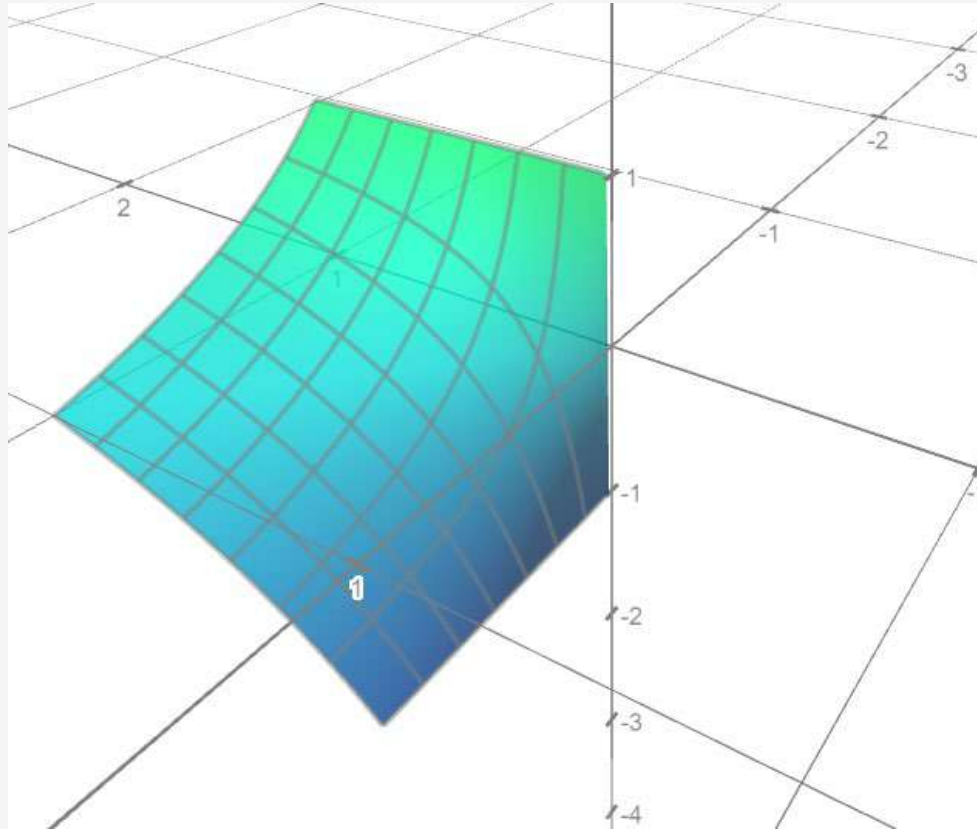
**Stressed Vegetation  
Reflectance**



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

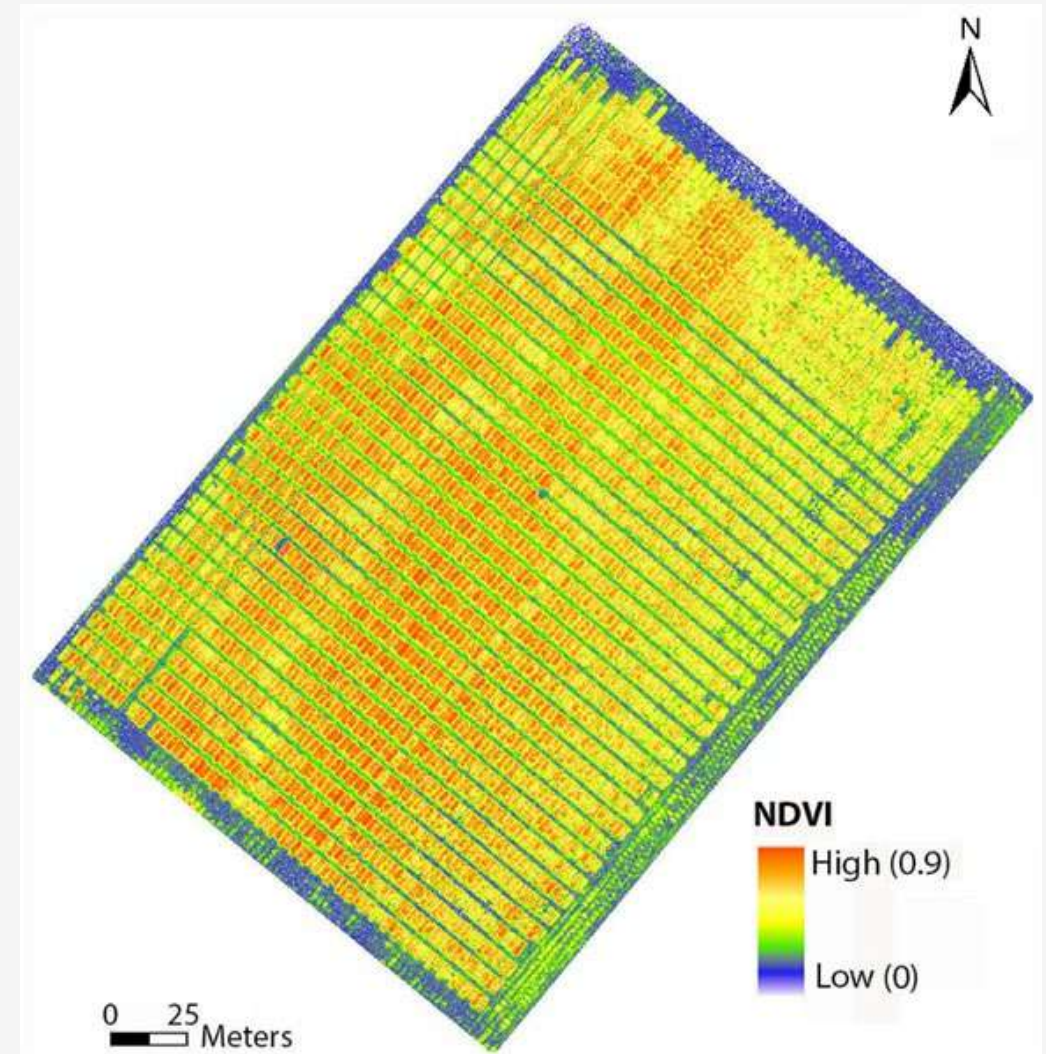


# Classical Approach: NDVI

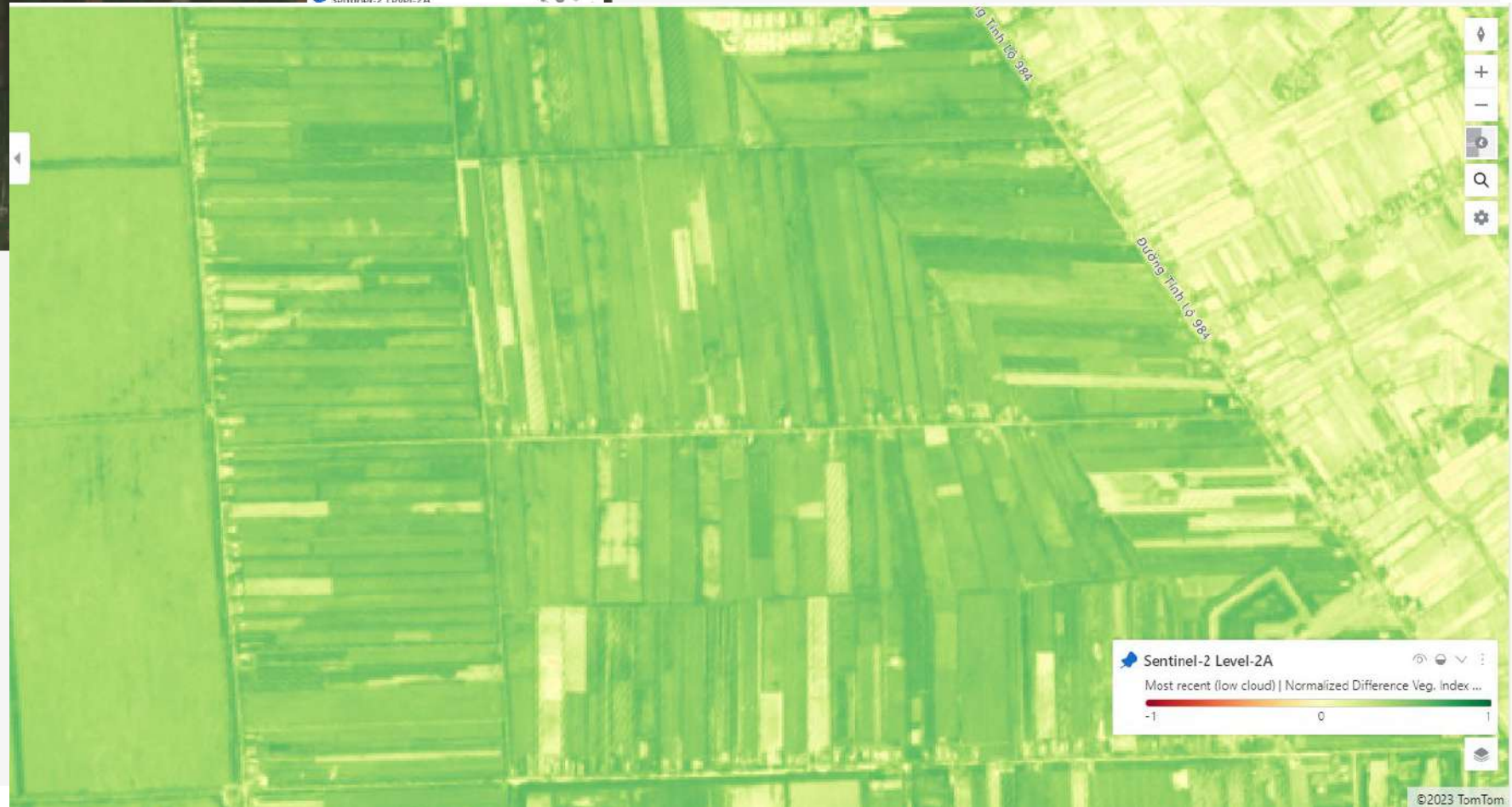
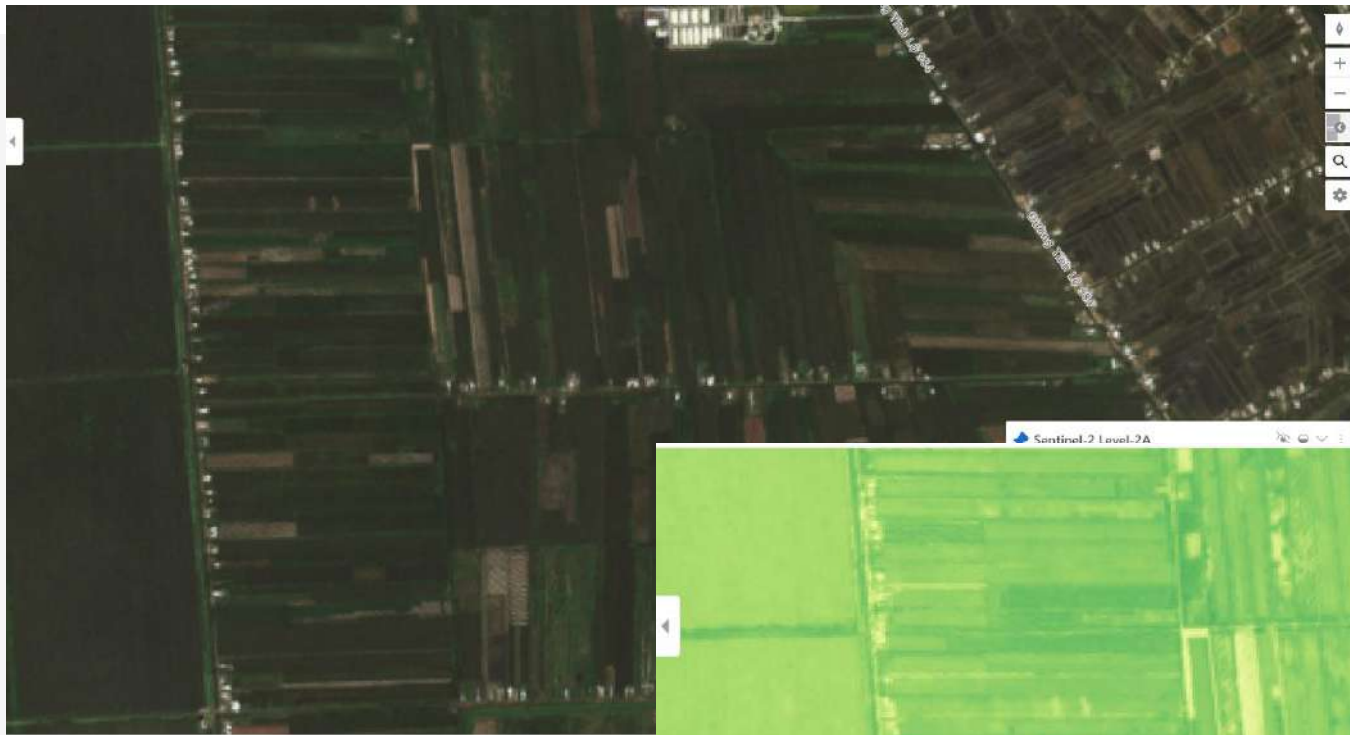


$$\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}}$$

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



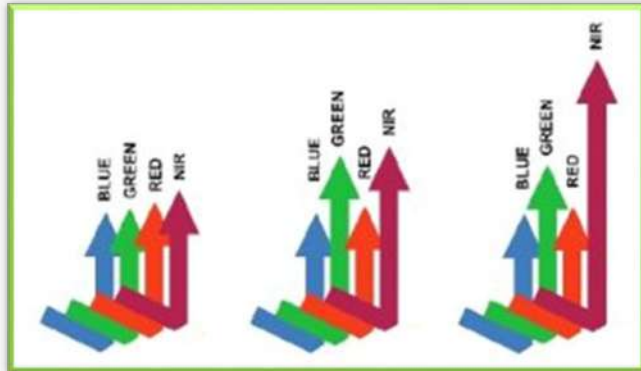
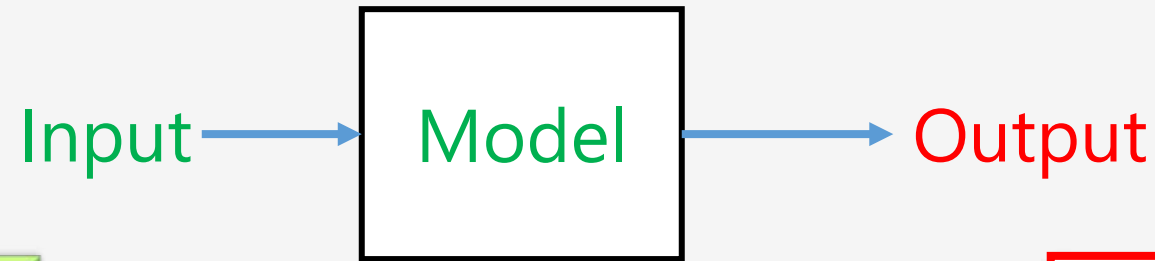




# Classical Approach: NDVI

Given  
Wanted

Classical Approach



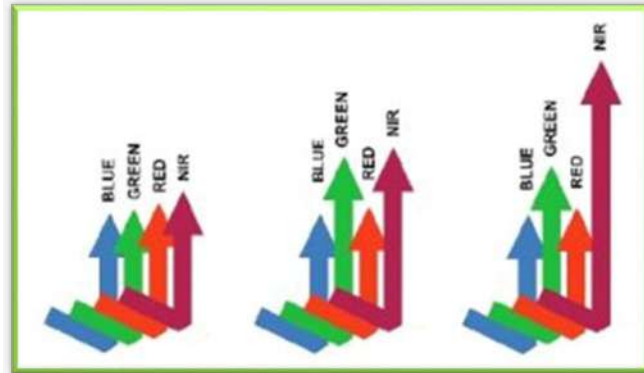
$$NDVI = \frac{NIR - Red}{NIR + Red}$$



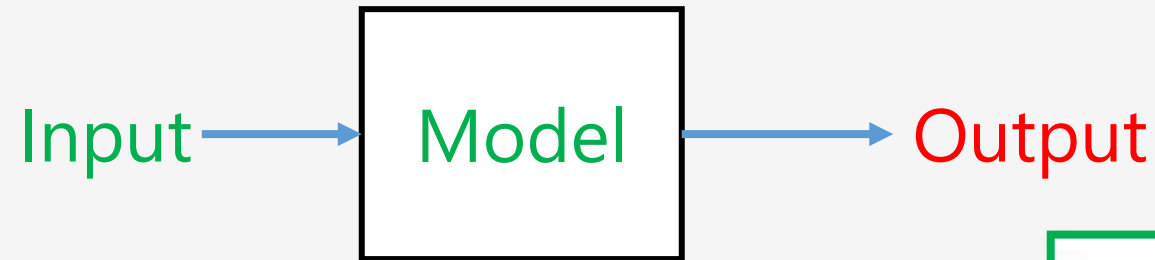


# Machine Learning vs. Classical Approach

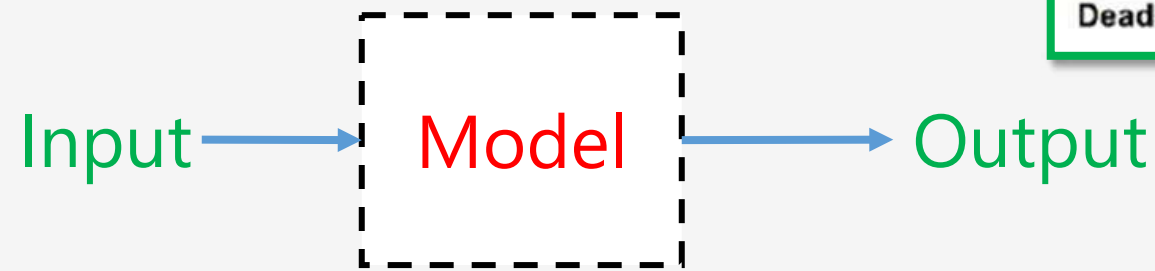
Given  
Wanted



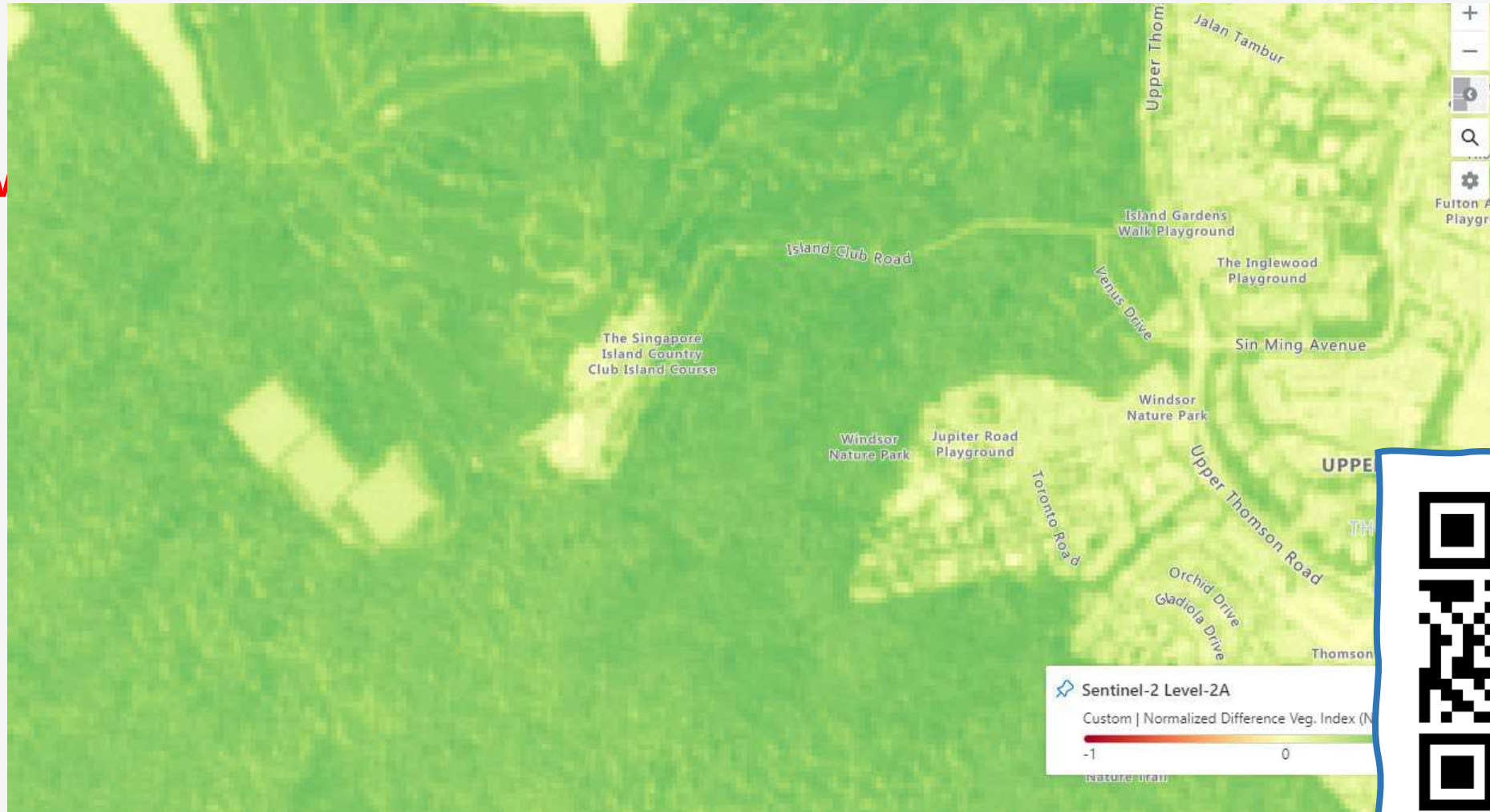
Classical Approach



Machine Learning



# Classical Approach: Tree/Grass Classification



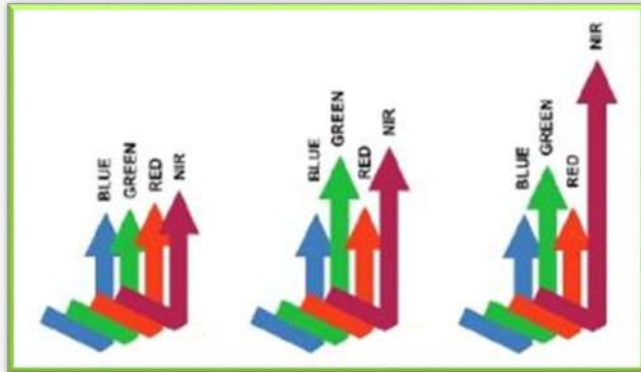
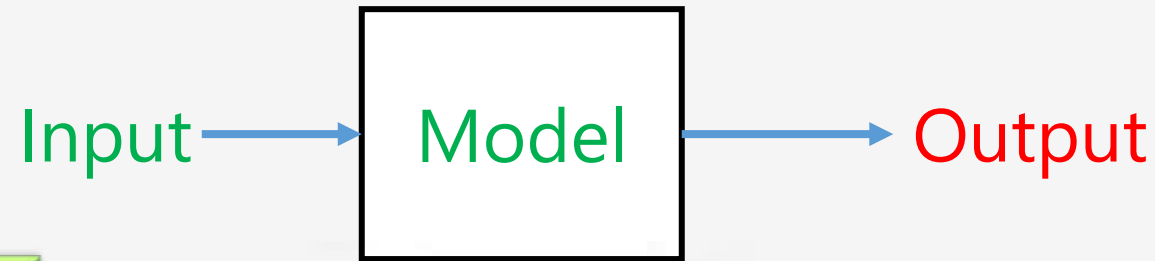
<https://www.menti.com/alaf1t425d72>



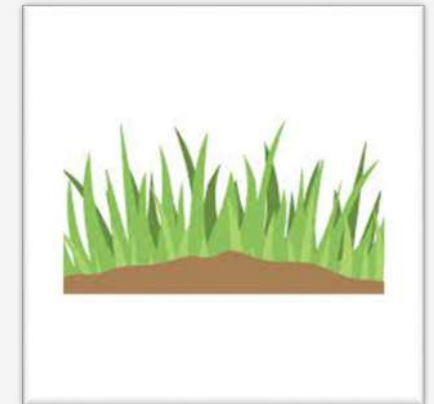
# Classical Approach: NDVI

 Given  
 Wanted

Classical Approach

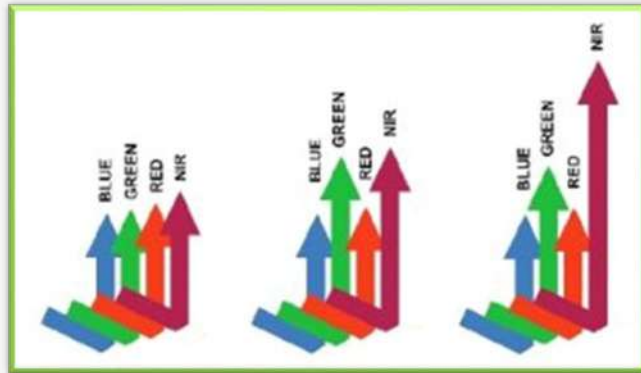


*New Formula*

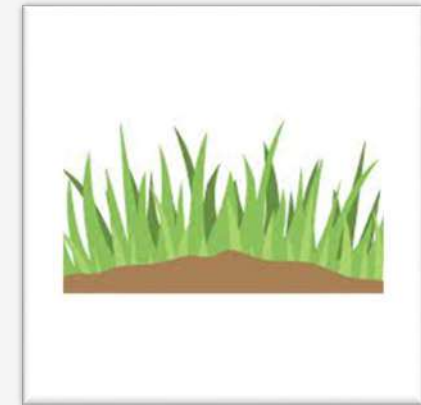
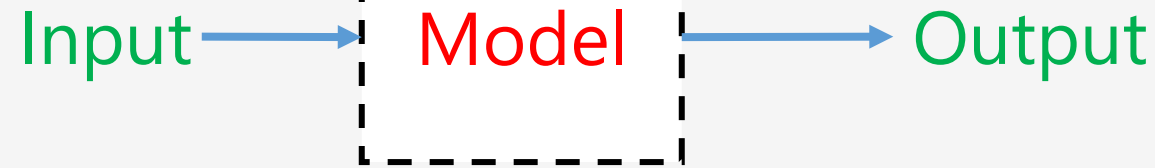


# Machine Learning vs. Classical Approach

 Given  
 Wanted

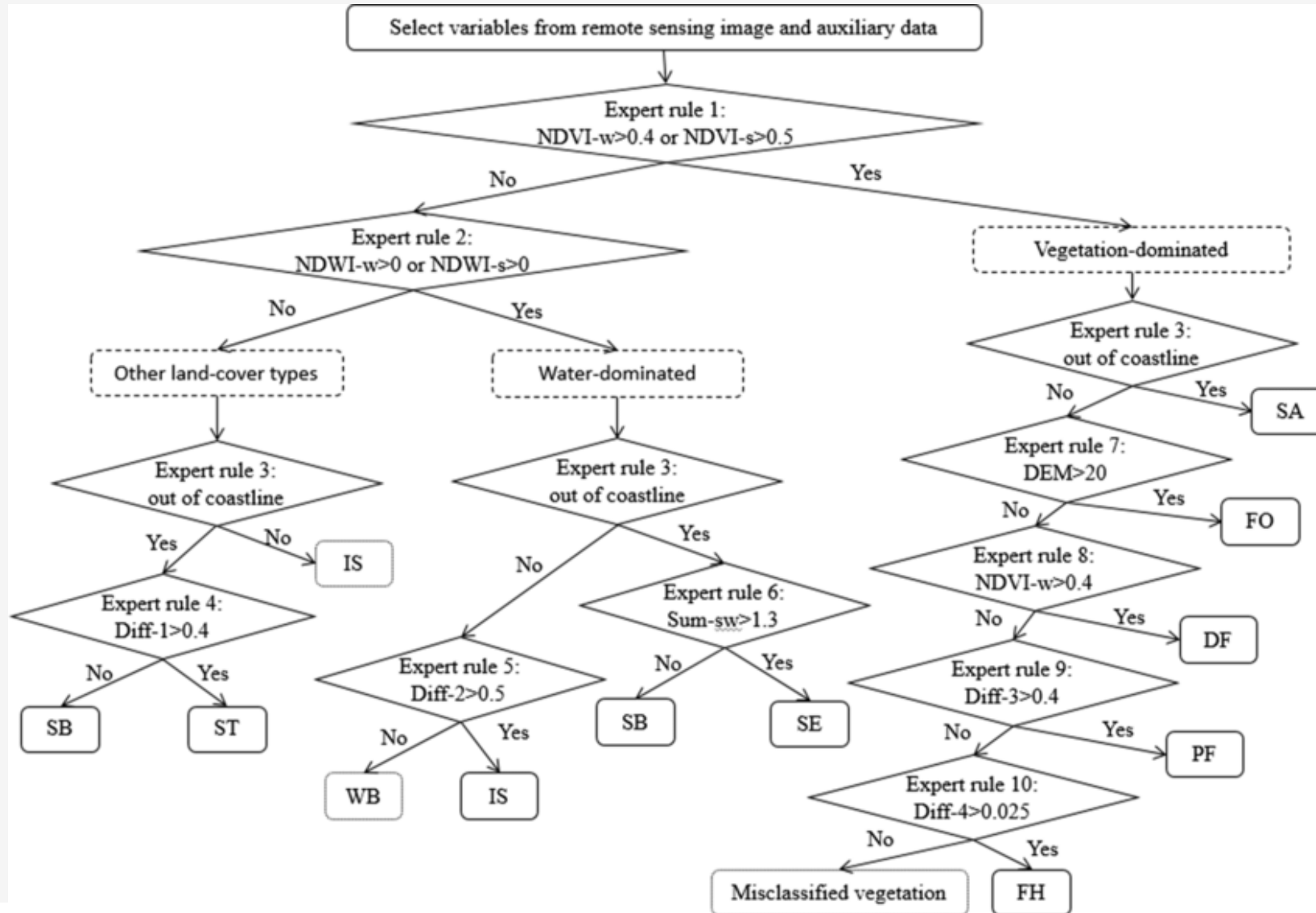


Machine Learning





# 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

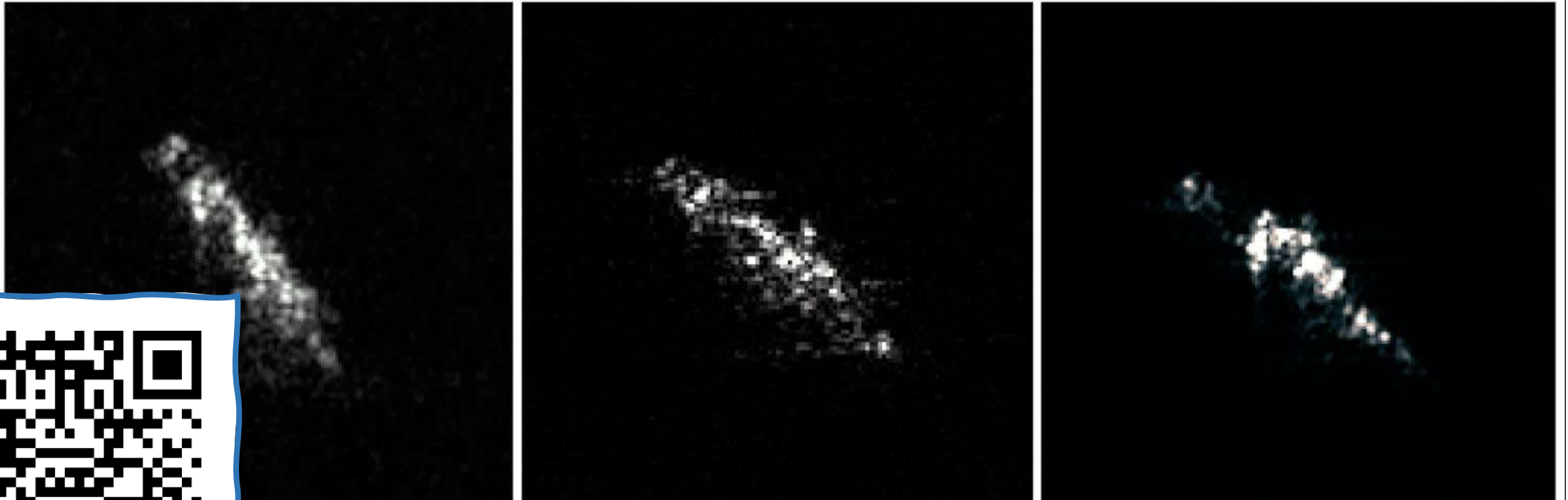


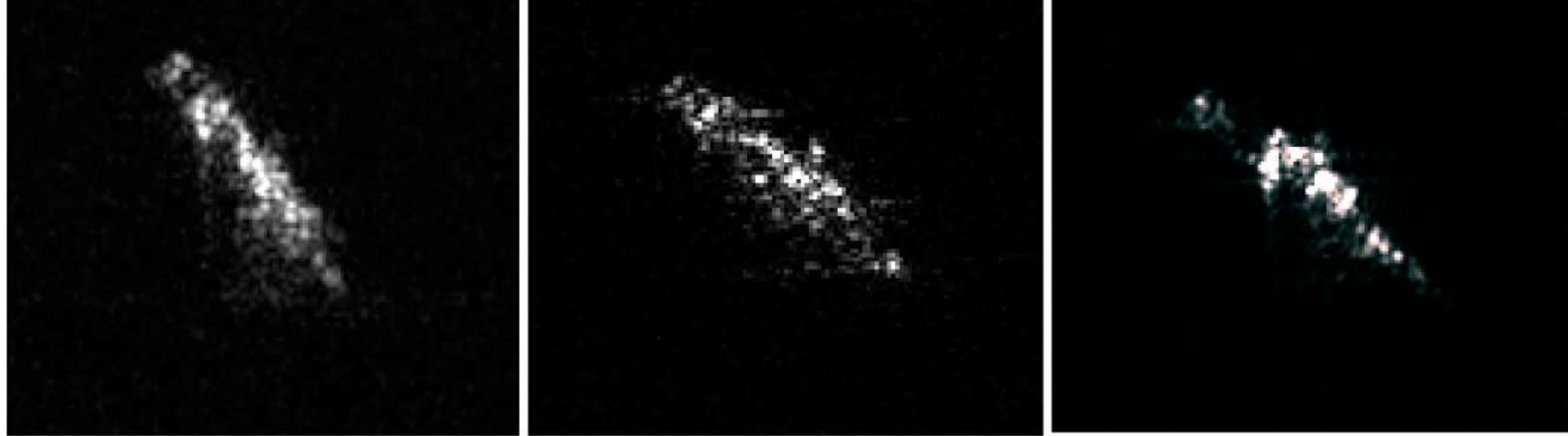
# Harder Task

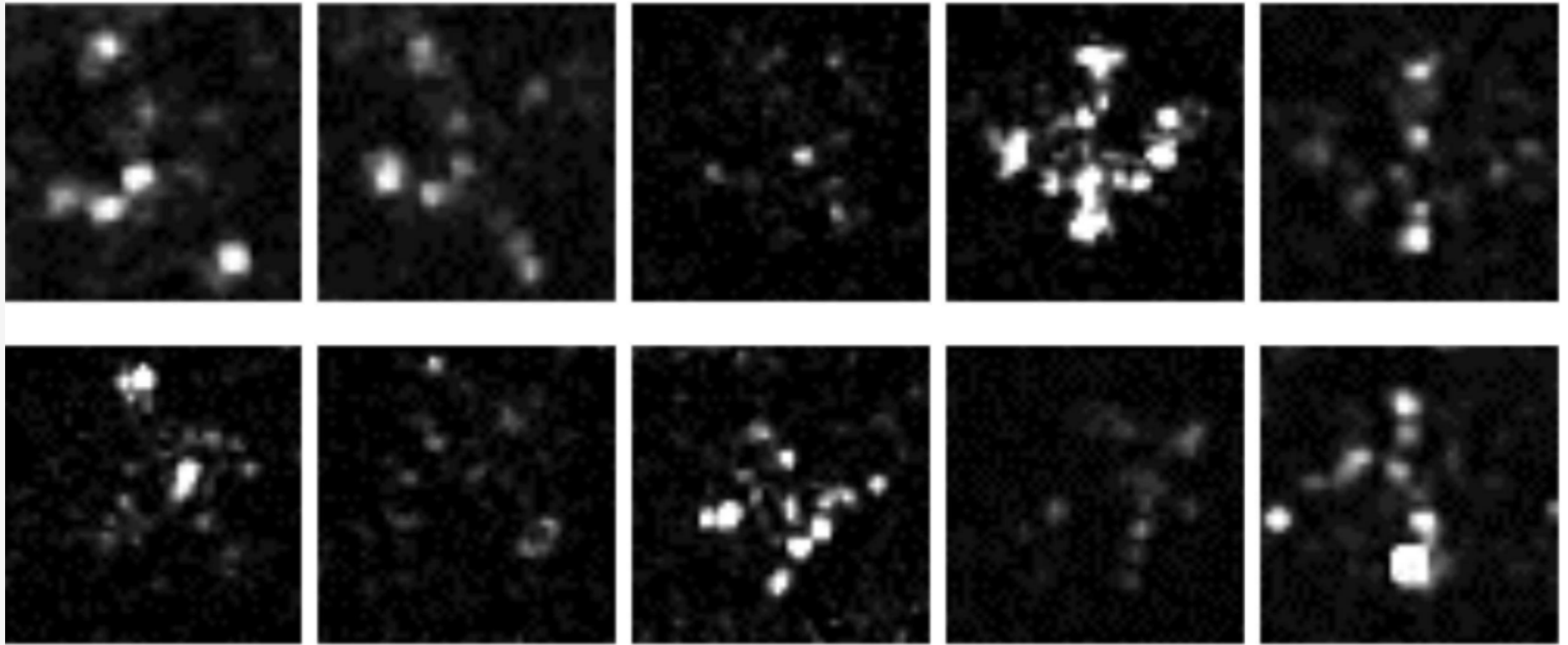


# Harder Task: SAR Classification

---







# 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



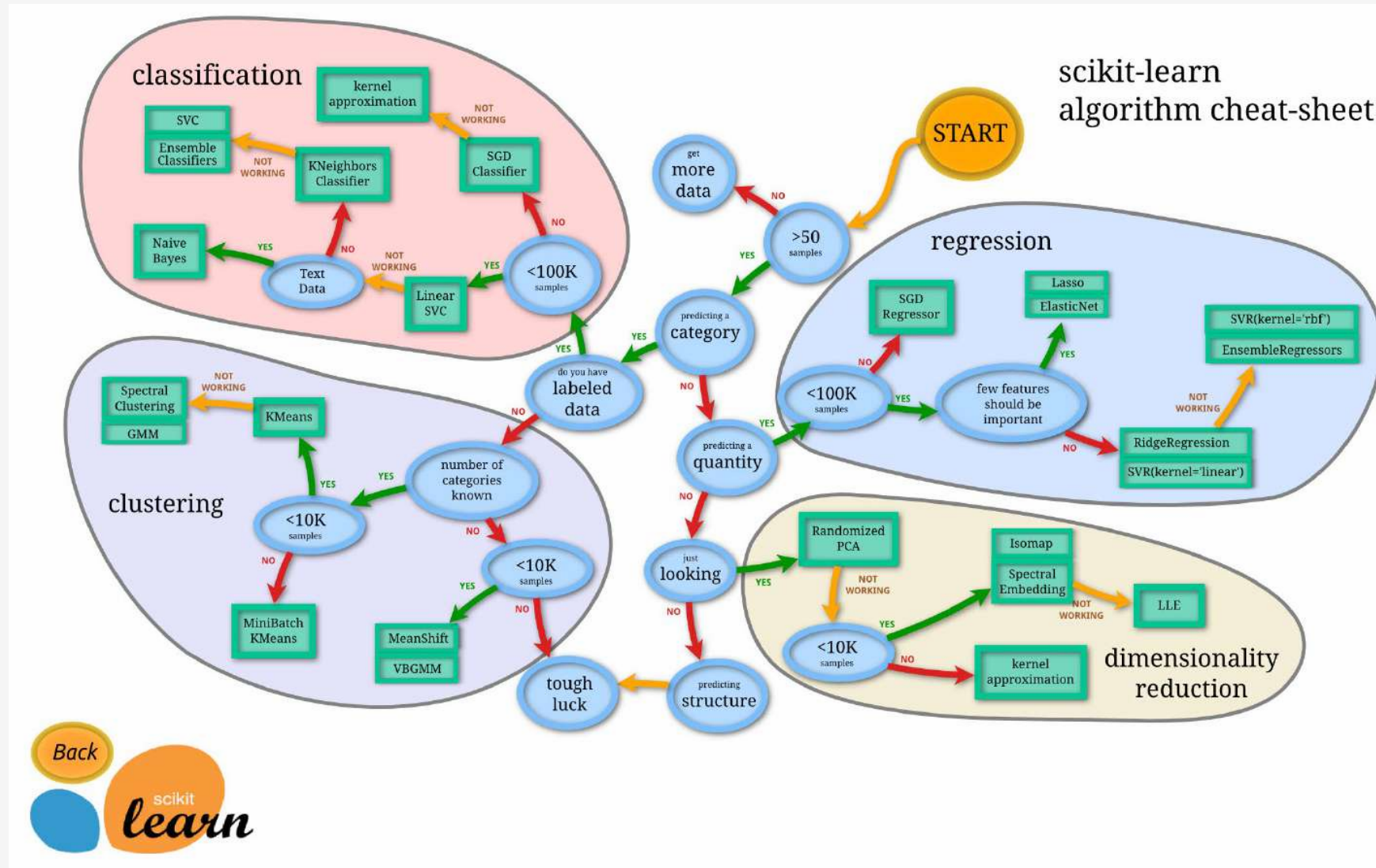
**Try to minimize cost function**

The diagram consists of two blue arrows. One arrow points from the word 'efficiently' in the quote above to the text 'Try to minimize cost function'. The other arrow points from the word 'performance' in the definition below to the same text 'Try to minimize cost function'.

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



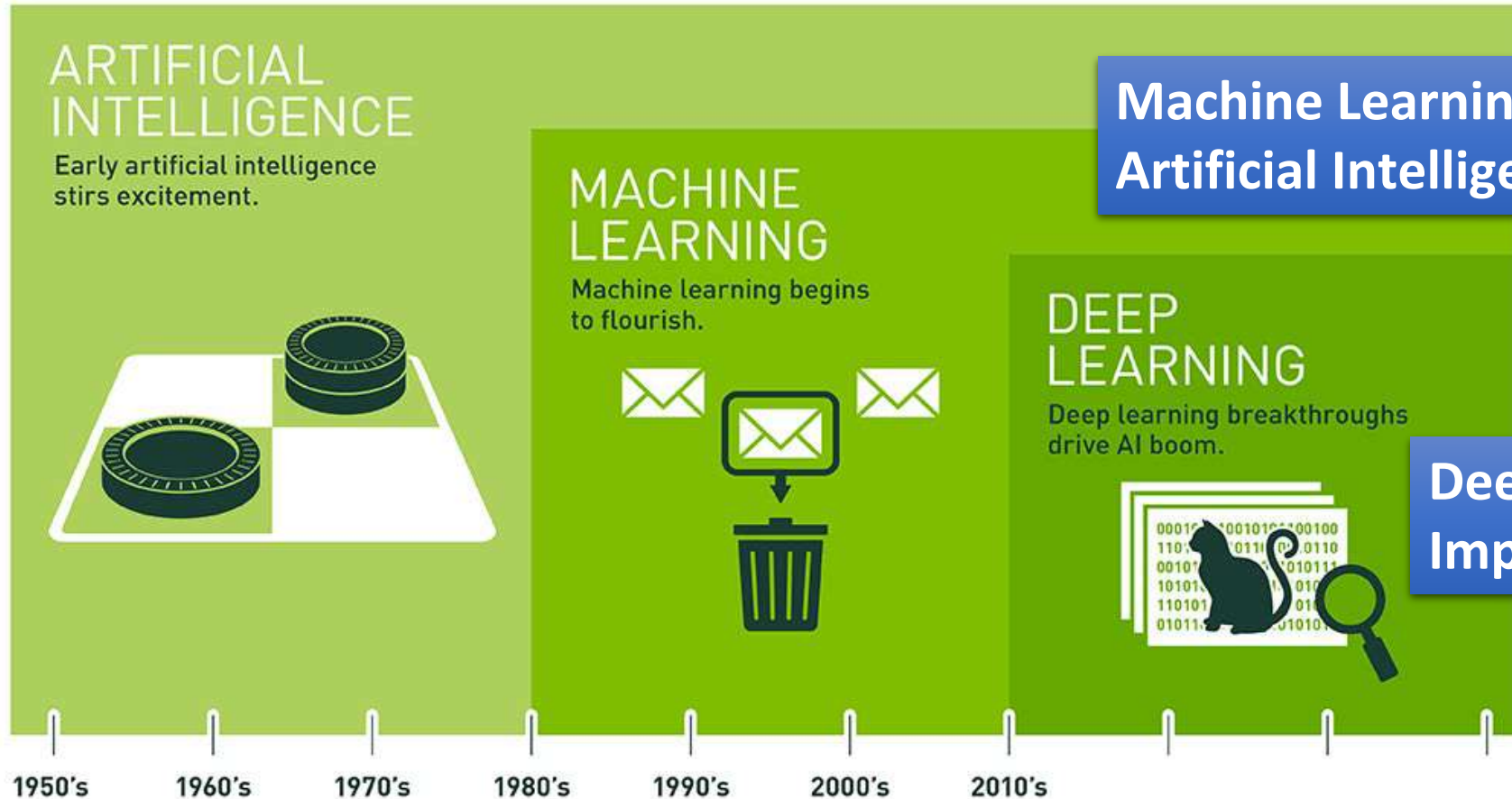
# Classical Machine Learning Methods





# Deep Learning

## Artificial Intelligence — Hand-coded Human Intelligence

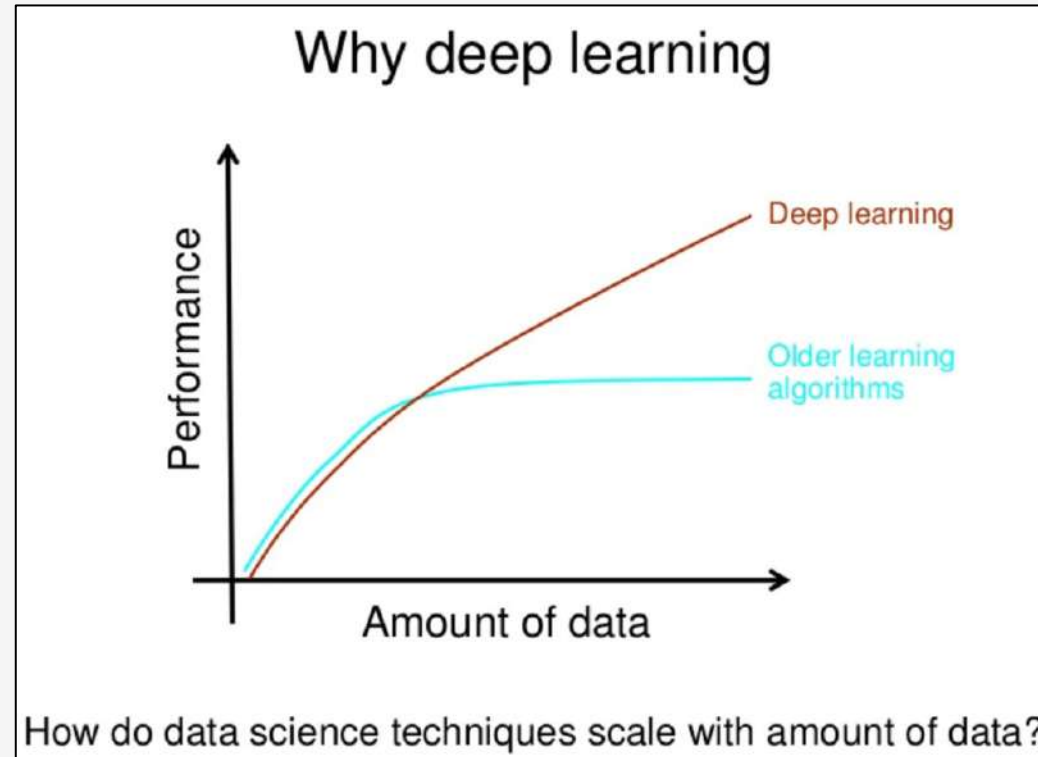


## Machine Learning — An Approach to Achieve Artificial Intelligence

## Deep Learning — A Technique for Implementing Machine Learning

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.

# Deep Learning



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



**Better results**

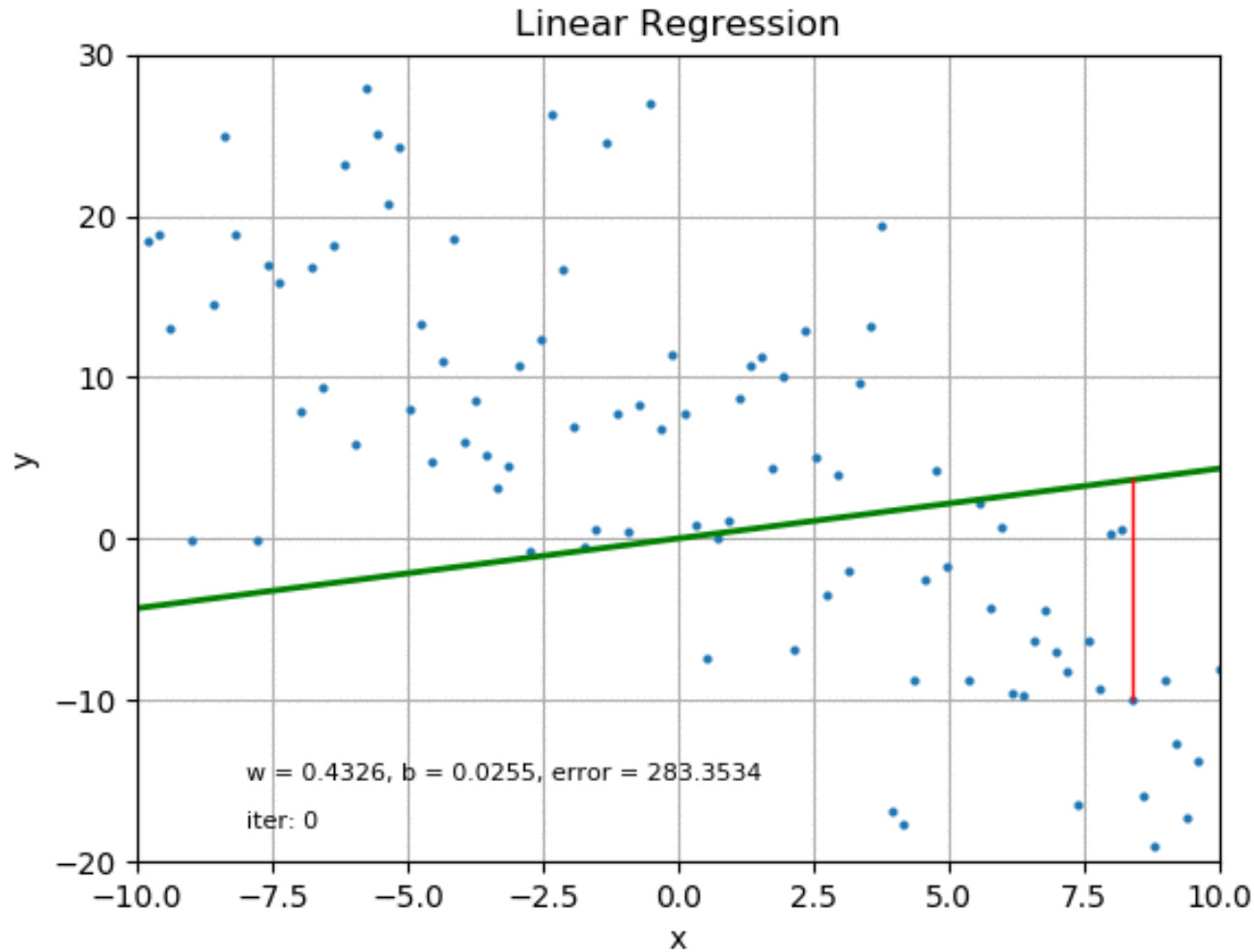


# Train A Model: Apple or Orange

The screenshot displays the Teachable Machine web interface. On the left, under the 'Teachable Machine' header, there are two class training panels. 'Class 1' is for 'Apples' and 'Class 2' is for 'Oranges'. Each class has '6 Image Samples' and buttons for 'Webcam' and 'Upload'. A 'Training' panel in the center shows 'Model Trained' and an 'Advanced' dropdown. On the right, a 'Preview' panel shows the 'Export Model' button, an 'Input' section with a toggle set to 'ON' and a 'File' dropdown, and two options to 'Choose images from your files, or drag & drop here' or 'Import images from Google Drive'. Below these is a large Apple logo representing the model's output, and an 'Output' section at the bottom.



# Fitting A Line



$$y = wx + b$$

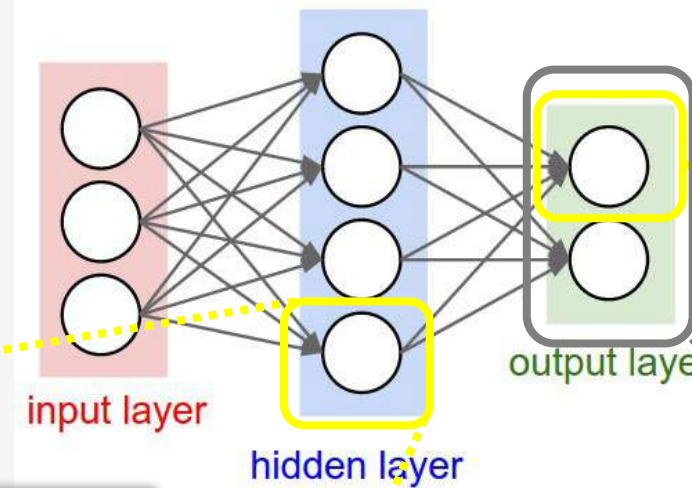
$$\Delta y = wx + b - y_0$$

$$\frac{\partial \Delta y}{\partial b} = 1$$

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



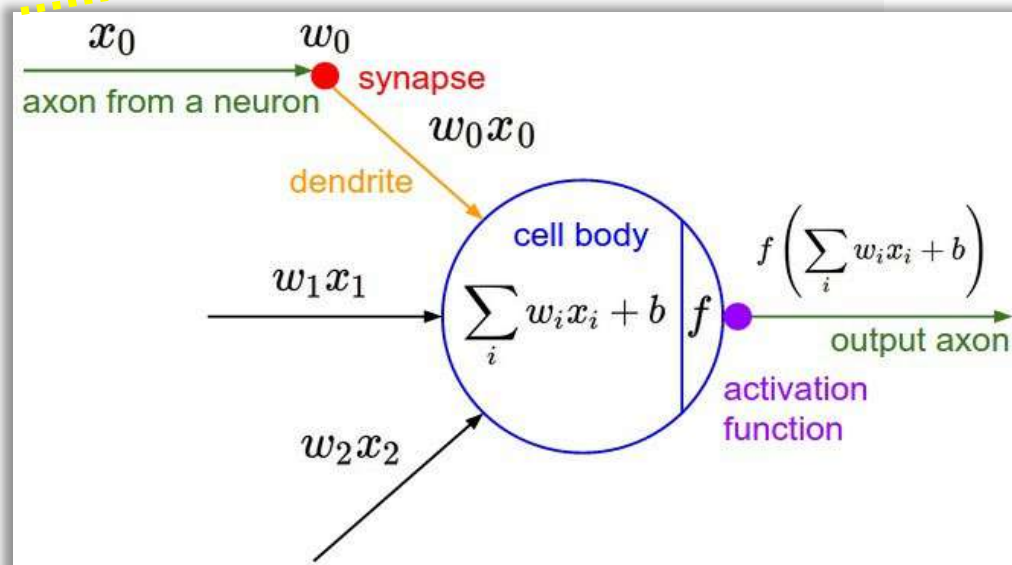
# Neural Network



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

Minimising

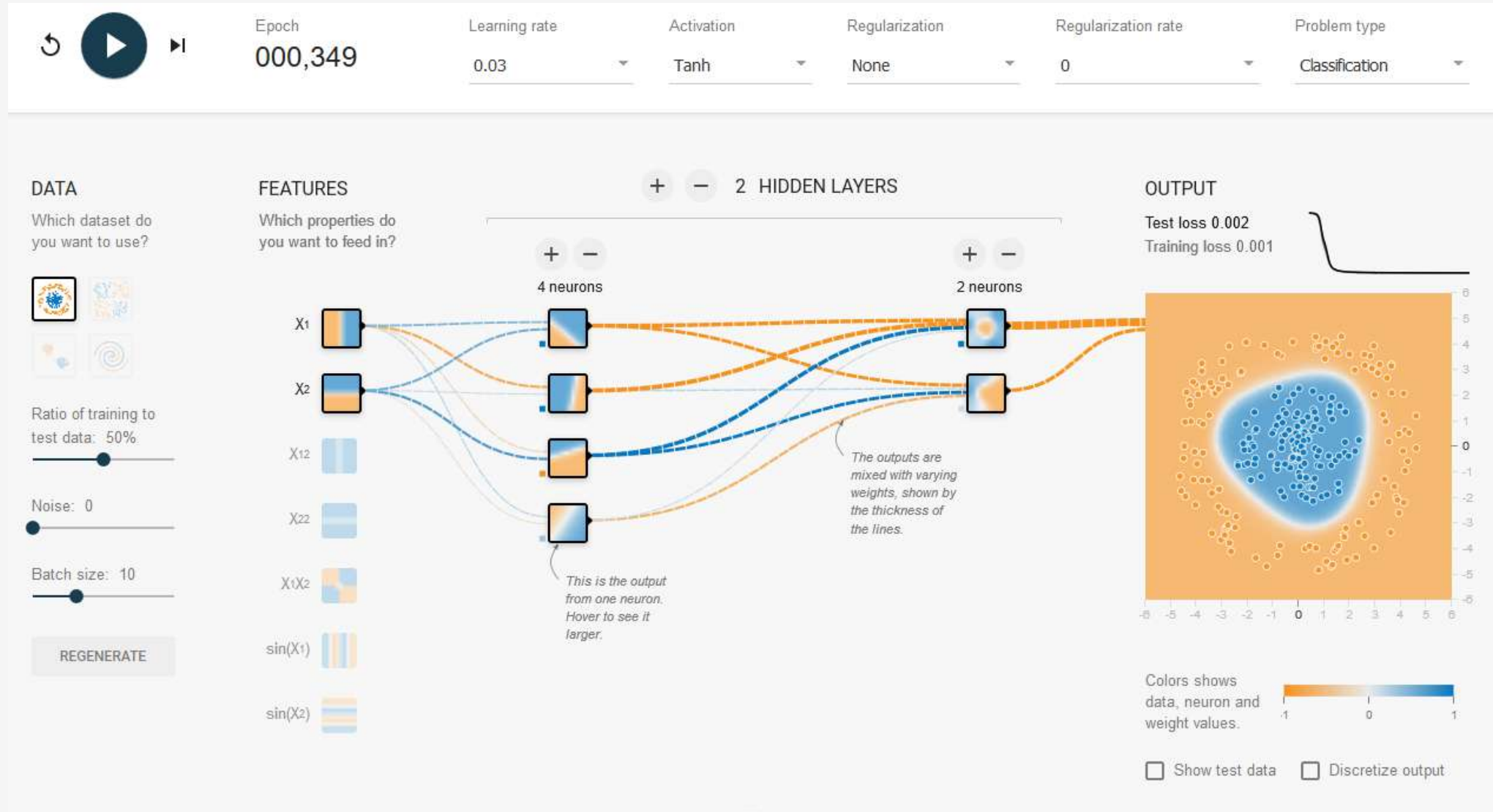
$$loss = -\sum_i y_i \log(p_i)$$



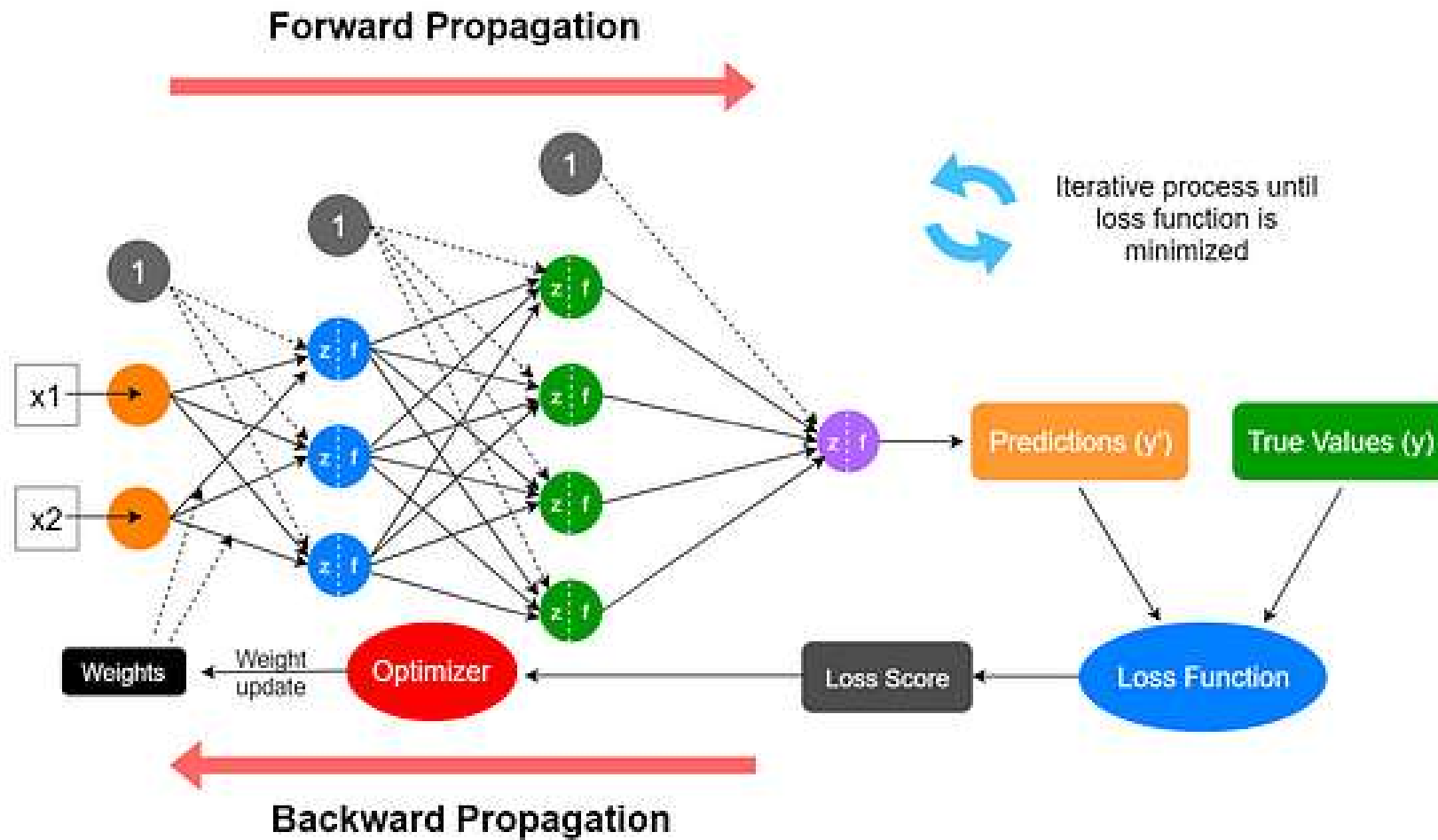
$$h = f\left(\sum_i w_i x_i + b\right)$$



# Neural Network



# Neural Network



# 1D -> 2D

---



Sequential NN

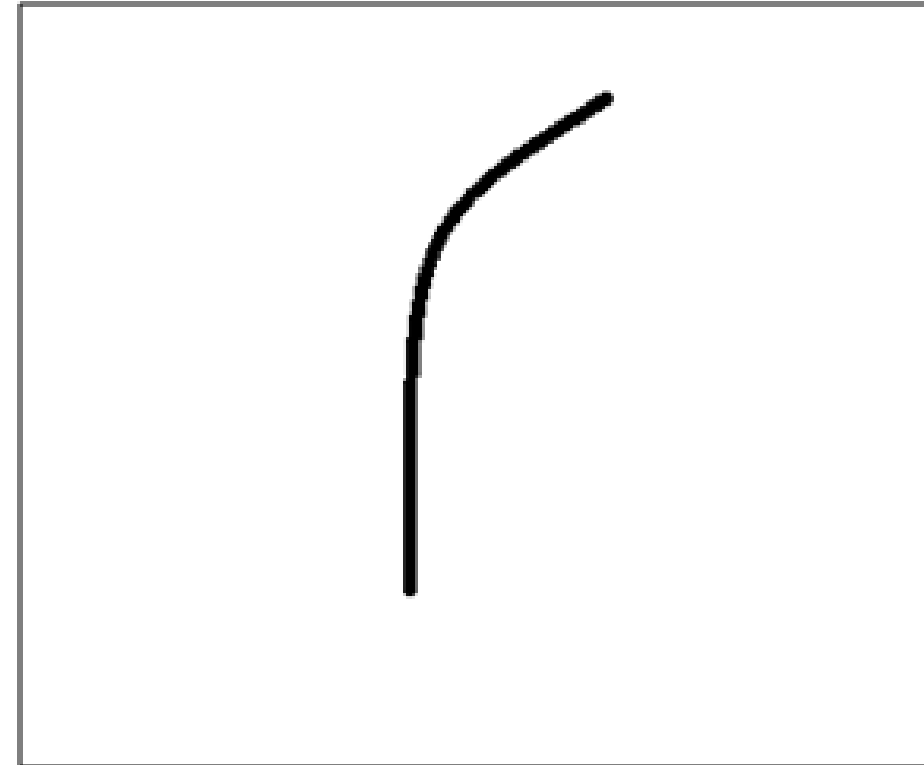


Convolutional NN

# Convolutional Neural Network

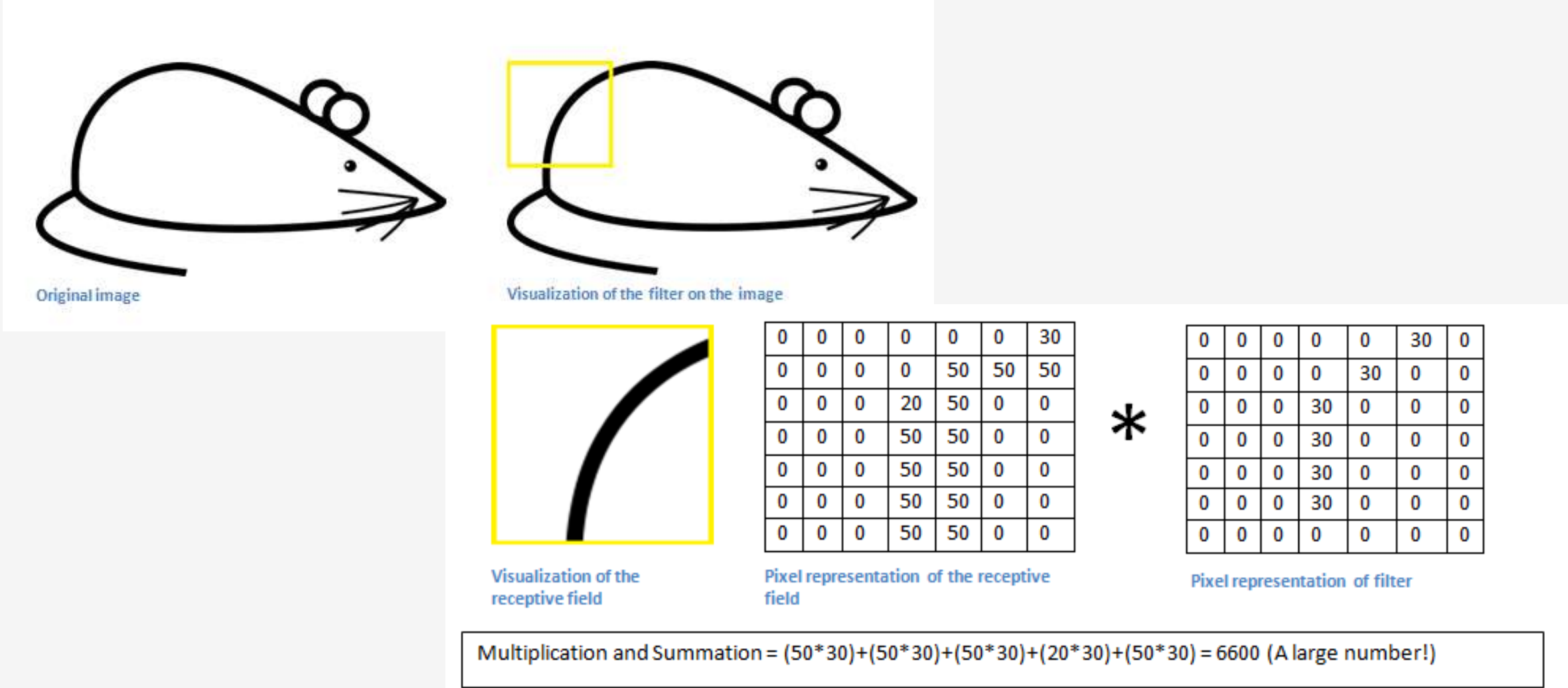
0	0	0	0	0	30	0
0	0	0	0	30	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	30	0	0	0
0	0	0	0	0	0	0

Pixel representation of filter



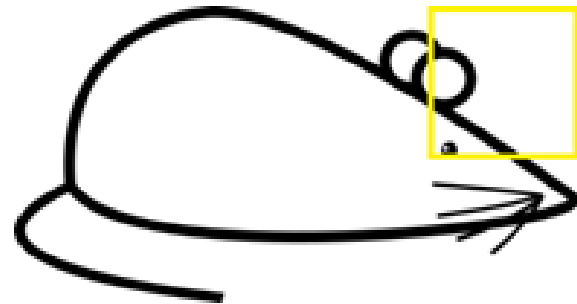
Visualization of a curve detector filter

# Convolutional Neural Network





# 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

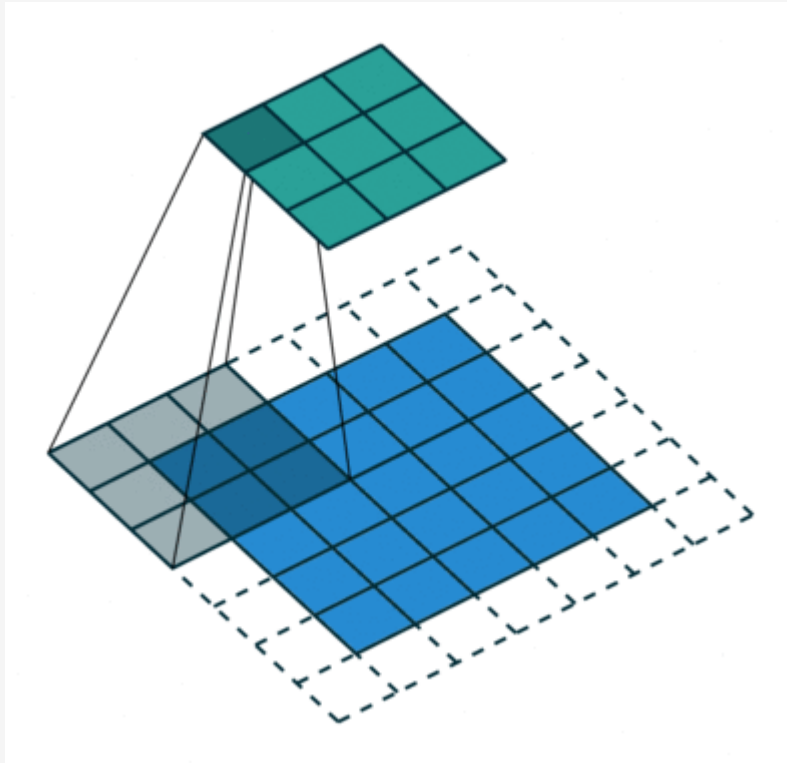
\*

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



0	0	0	0	0	0	...
0	156	155	156	158	158	...
0	153	154	157	159	159	...
0	149	151	155	158	159	...
0	146	146	149	153	158	...
0	145	143	143	148	158	...
...	...	...	...	...	...	...

Input Channel #1 (Red)

0	0	0	0	0	0	...
0	167	166	167	169	169	...
0	164	165	168	170	170	...
0	160	162	166	169	170	...
0	156	156	159	163	168	...
0	155	153	153	158	168	...
...	...	...	...	...	...	...

Input Channel #2 (Green)

0	0	0	0	0	0	...
0	163	162	163	165	165	...
0	160	161	164	166	166	...
0	156	158	162	165	166	...
0	155	155	158	162	167	...
0	154	152	152	157	167	...
...	...	...	...	...	...	...

Input Channel #3 (Blue)

-1	-1	1
0	1	-1
0	1	1

Kernel Channel #1



308

1	0	0
1	-1	-1
1	0	-1

Kernel Channel #2



-498

0	1	1
0	1	0
1	-1	1

Kernel Channel #3



164

+

+



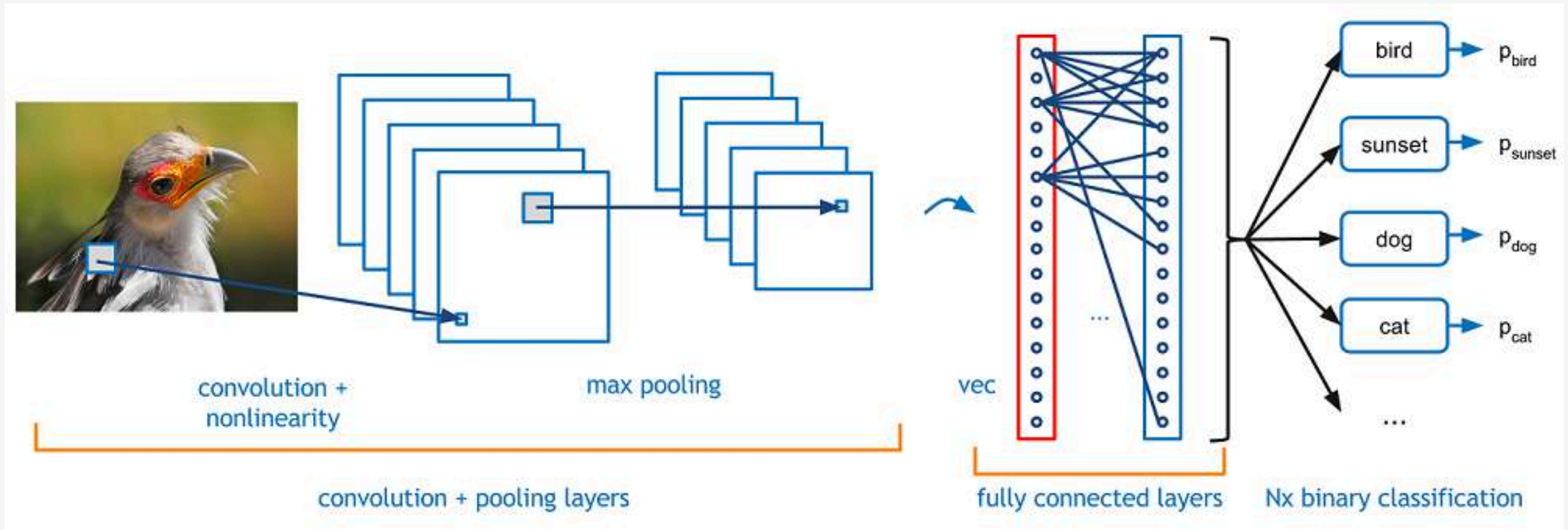
Bias = 1

+ 1 = -25

-25			...
			...
			...
			...
...	...	...	...

Output

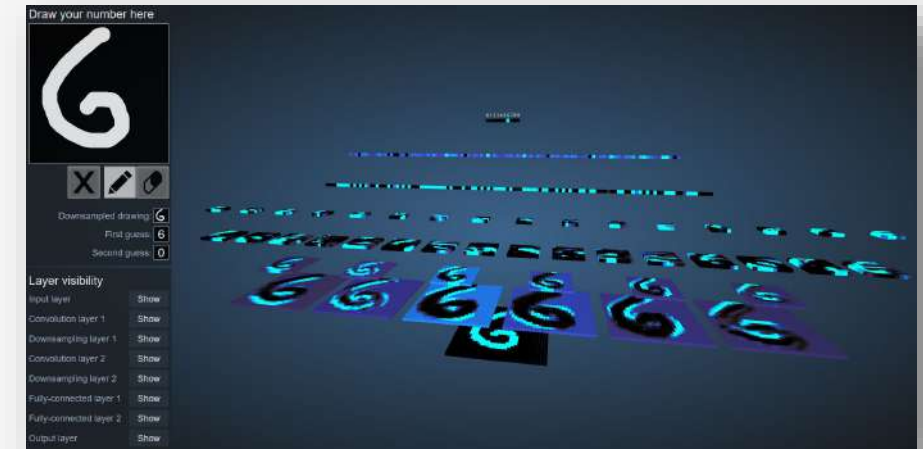
# Convolutional Neural Network



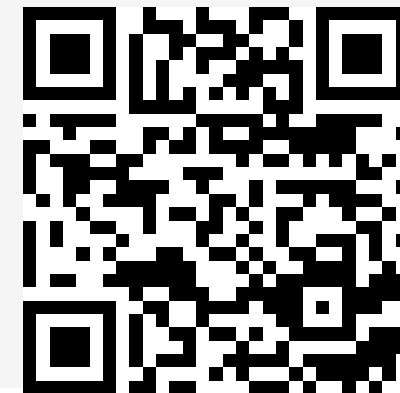
# Visualization of CNN



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



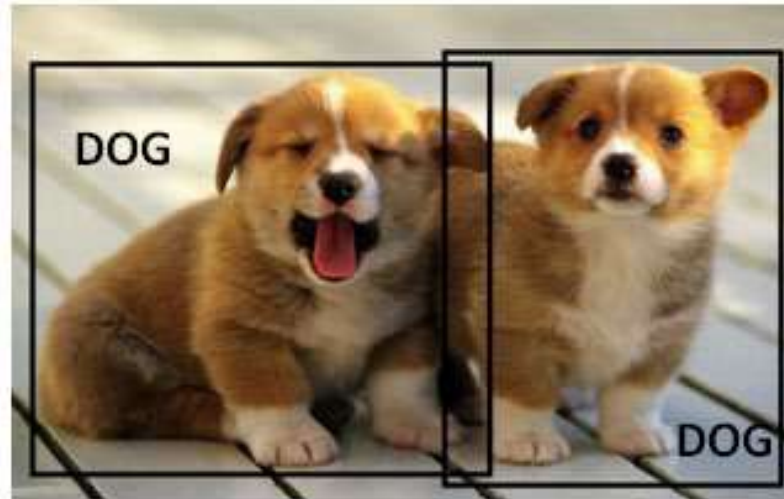
[https://adamharley.com/nn\\_vis/cnn/3d.html](https://adamharley.com/nn_vis/cnn/3d.html)



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



# Landcover Classification (SAR)



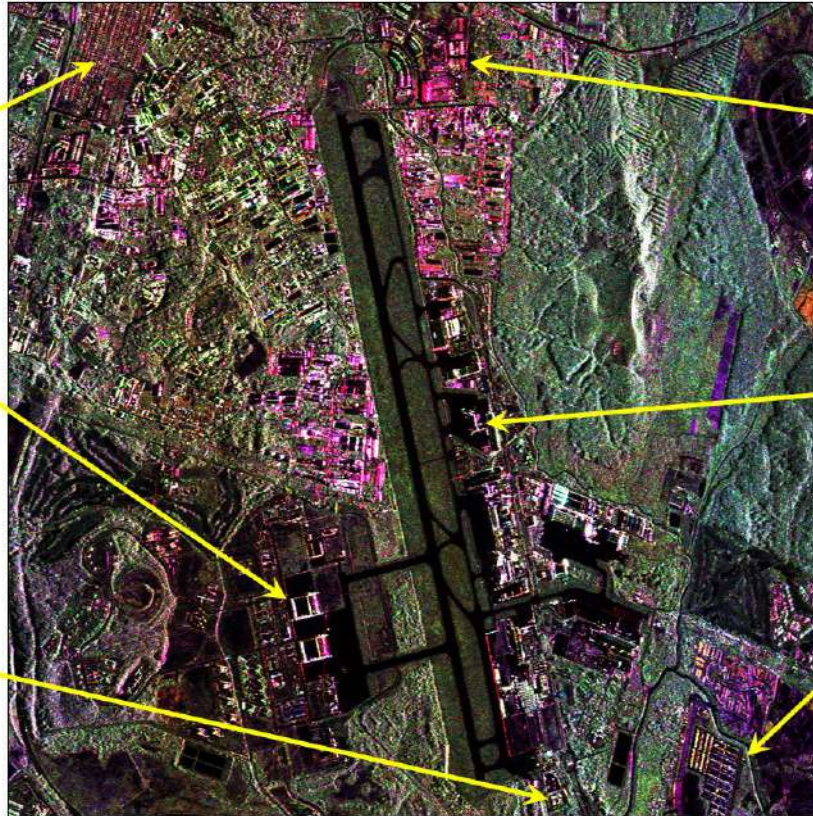
Residential estate



Hangars



Fuel depot



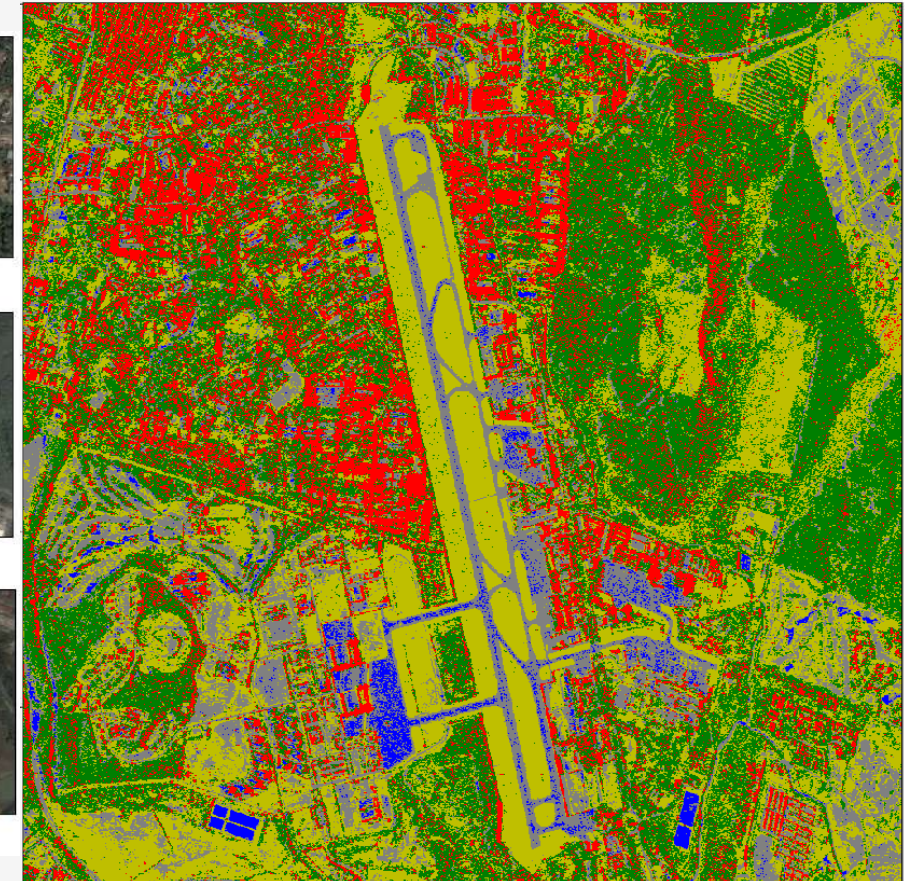
Residential flats



Terminal



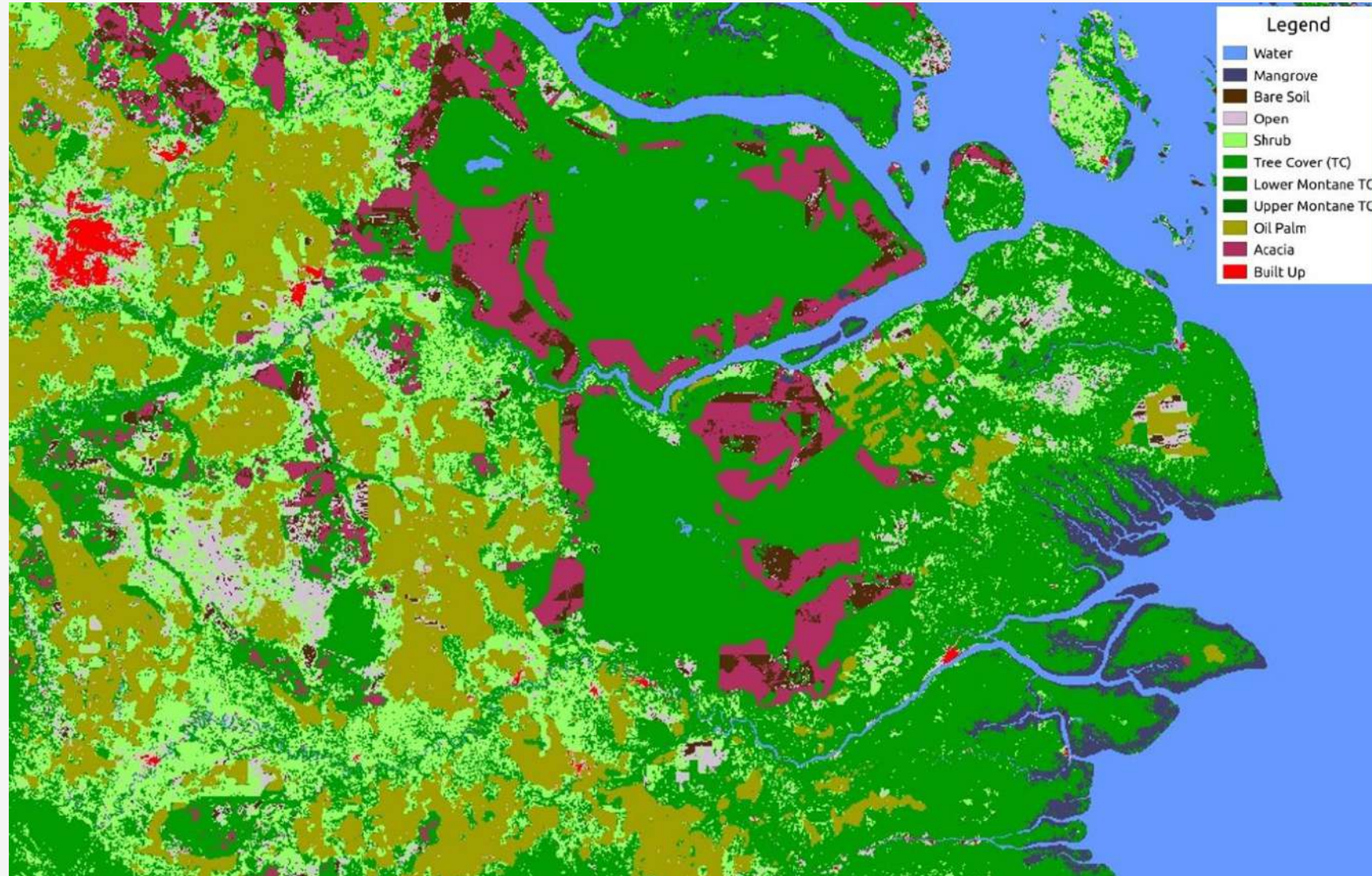
Light industrial buildings



- Runway
- Grassland
- Tree-cover
- Waterbody
- Building



# Landcover Classification (SAR+Optical)



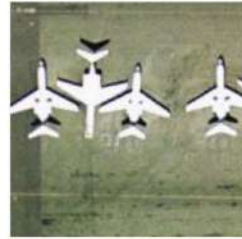
2021 CRISP land cover map over Riau, Sumatra



# Land Use Classification



**Agriculture**



**Airplane**



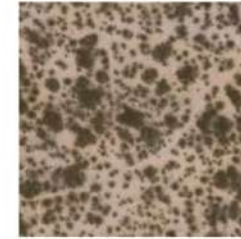
**Baseball diamond**



**Beach**



**Buildings**



**Chaparral**



**Dense residential**



**Forest**



**Freeway**



**Golf course**



**Harbor**



**Intersection**



**Medium residential**



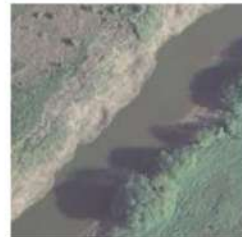
**Mobile home park**



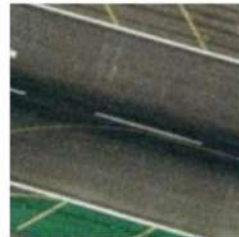
**Overpass**



**Parking lot**



**River**



**Runway**



**Sparse residential**

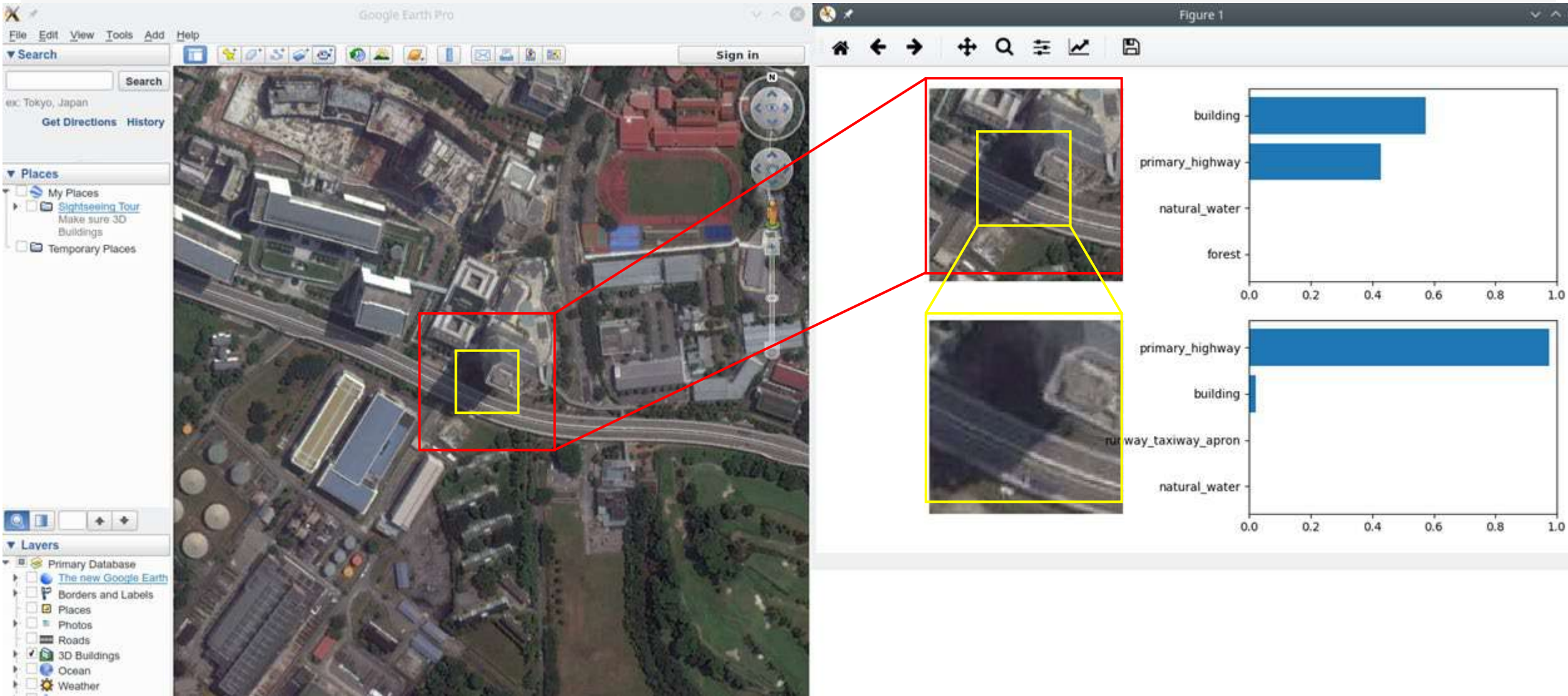


**Storage tanks**



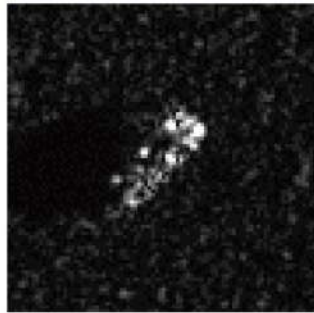
**Tennis court**

# Land Use Classification

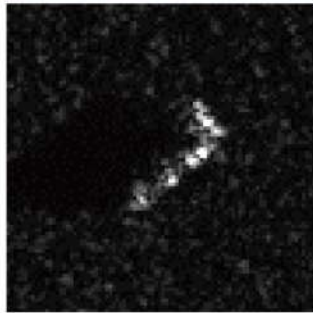




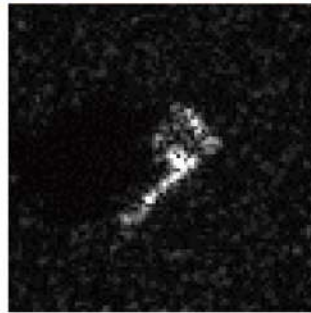
# SAR Target Classification



(1) BTR-60



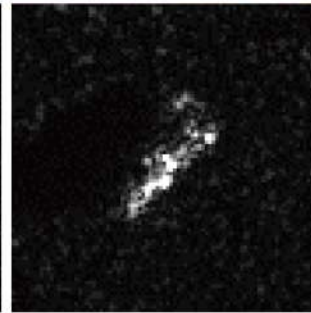
(2) BTR-70



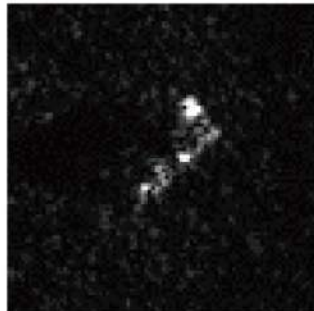
(3) T-72



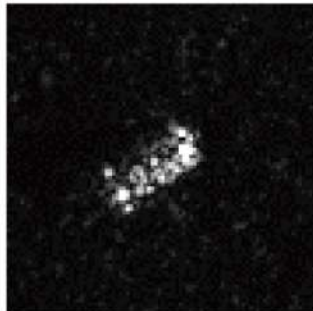
(4) T-62



(5) 2S1



(6) BRDM-2



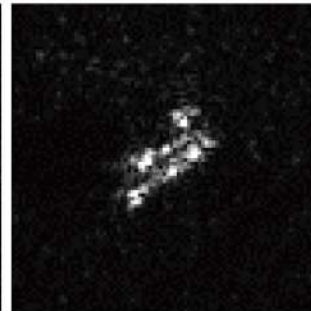
(7) D7



(8) BMP-2



(9) ZIL-131



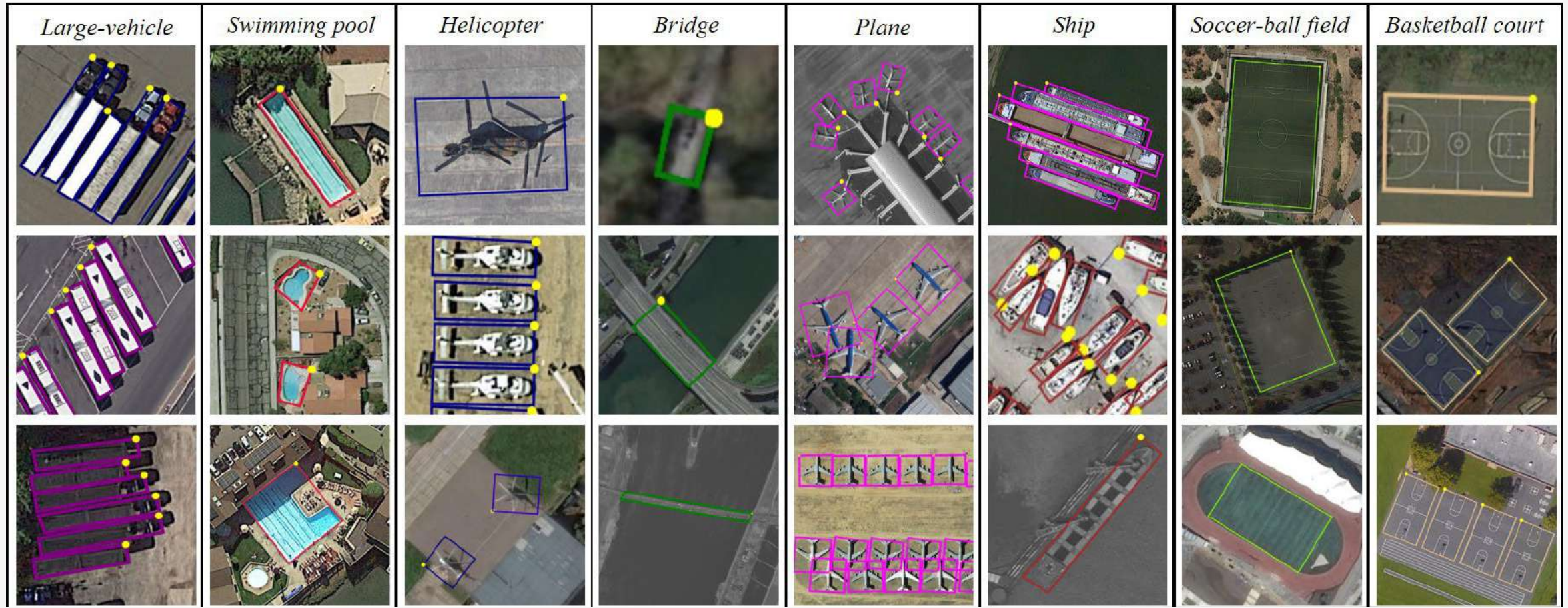
(10) ZSU-234

# Ship Detection





# Object Detection





# Object Detection

CRISP WebGIS Home 0 0 0 [Submit Changes](#)

Category

☒ Category

Search...

- ☒ Airplane
- ☒ Baseball Field
- ☒ Basketball Court
- ☒ Bridge
- ☒ Building: High
- ☒ Building: Industrial
- ☒ Building: Low
- ☒ Building: UNKNOWN
- ☒ Cloud

Filter

Filter...

Feature

Features: 1

layer\_22MAY12034003-S3XS\_R2C1-WV0320220512034003-AI-1\_3.150

ol_uid	geometry
21273	Polygon
category	category short
Storage Tank	ST

Main Map

200 m

© OpenStreetMap contributors.

Map 2

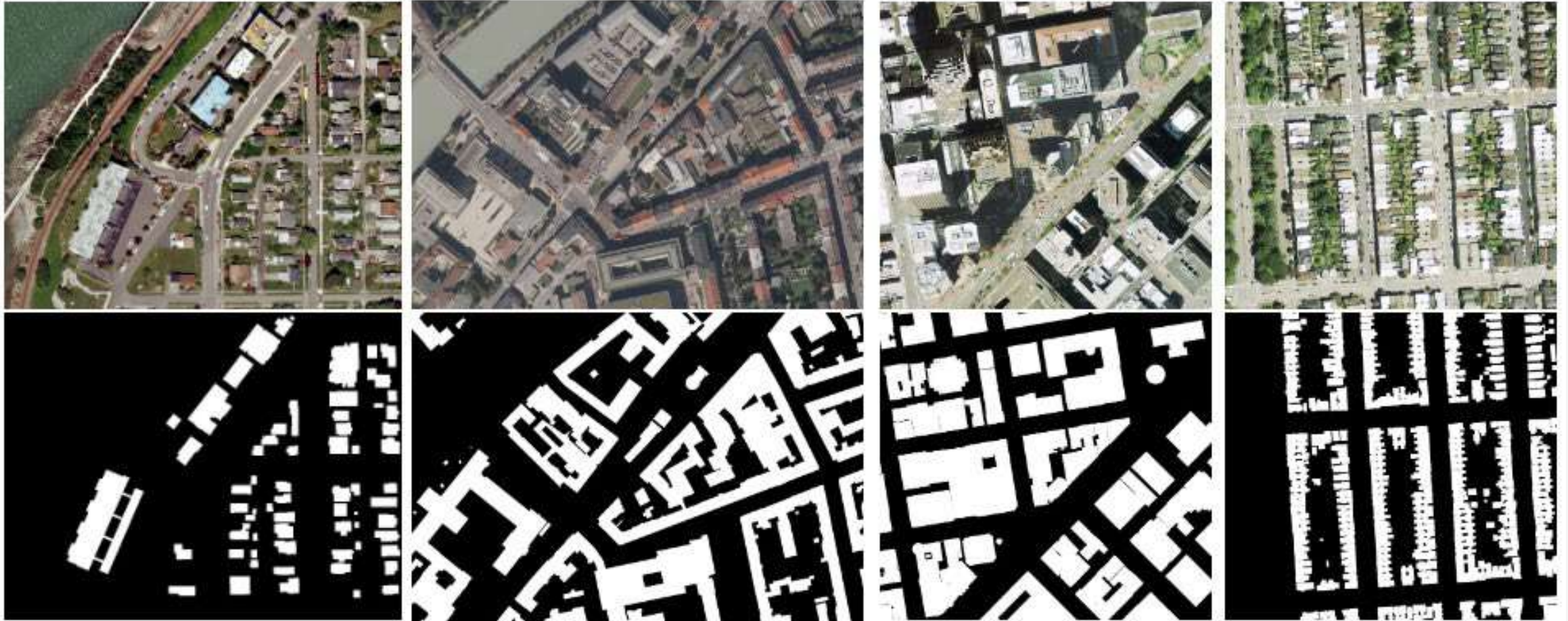
104.1888, 1.3428

200 m

© OpenStreetMap contributors.



# Building Segmentation





# Machine Learning in GEE

## •Supervised Classification:

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



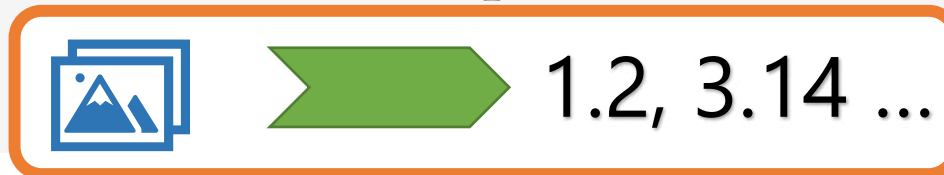
## •Unsupervised Classification:

- **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`

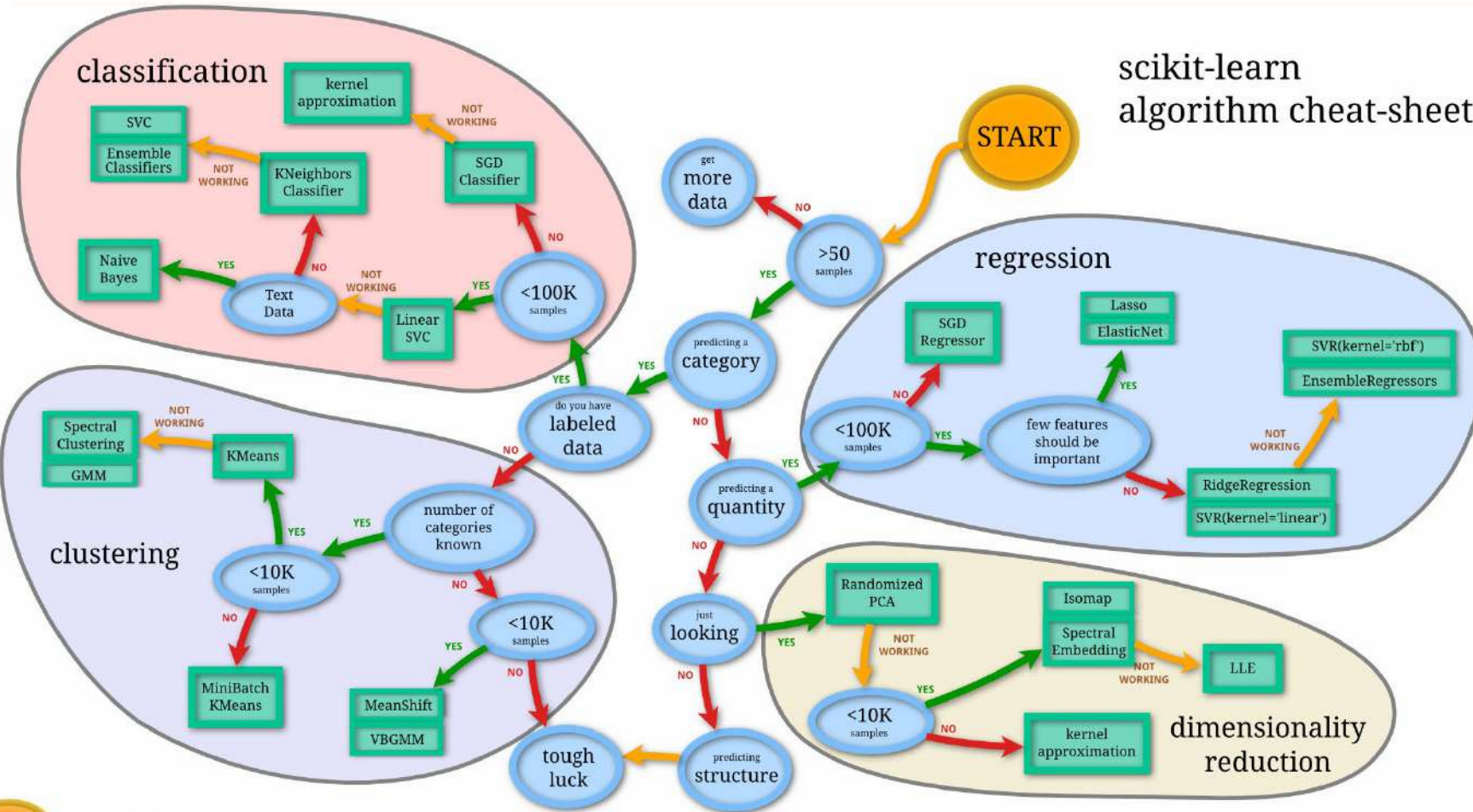
- **Unsupervised Classification:**

- `ee.Clustere`

- **Regression:**

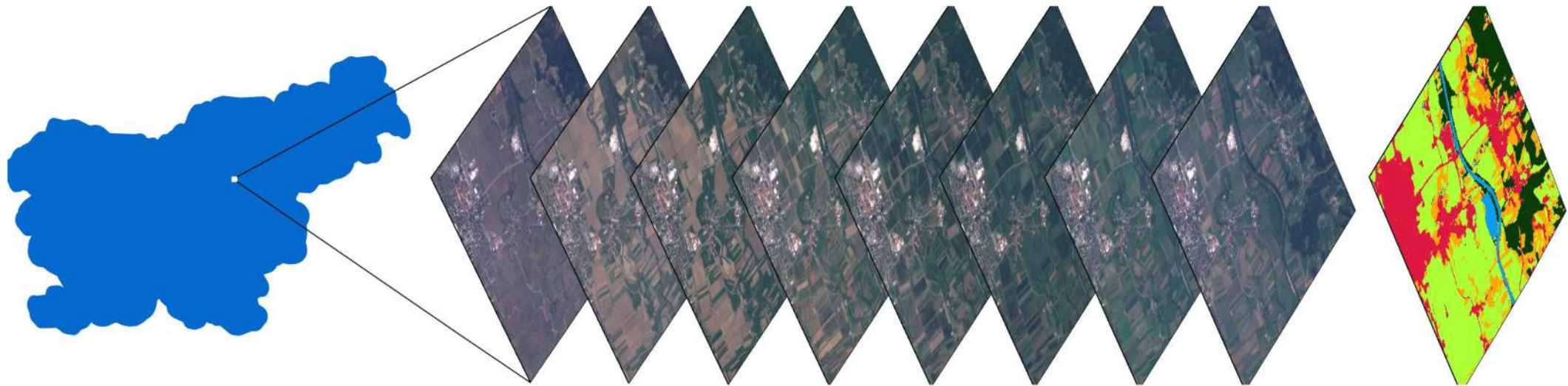
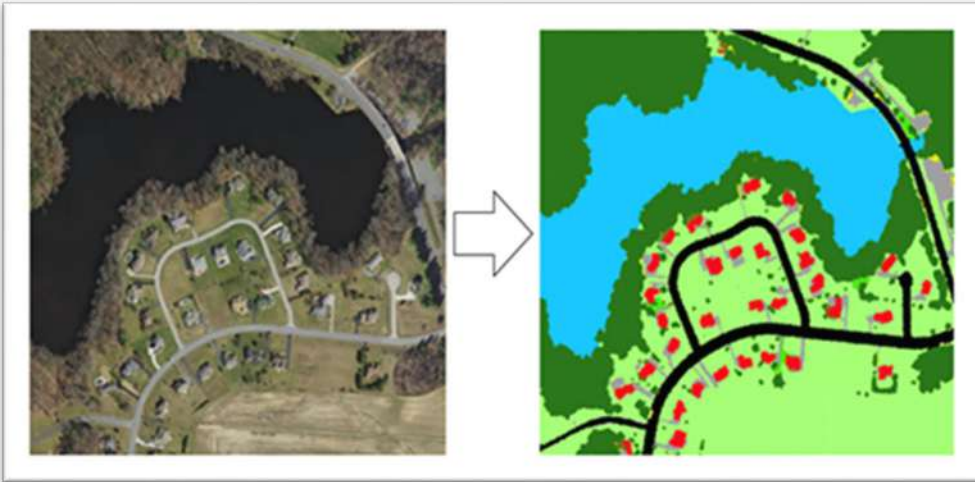
- linear regression using reducers:
- `ee.Reducer.linearFit()`
- `ee.Reducer.linearRegression()`
- `ee.Reducer.robustLinearRegression()`
- `ee.Reducer.ridgeRegression()`

# Classical Machine Learning Methods



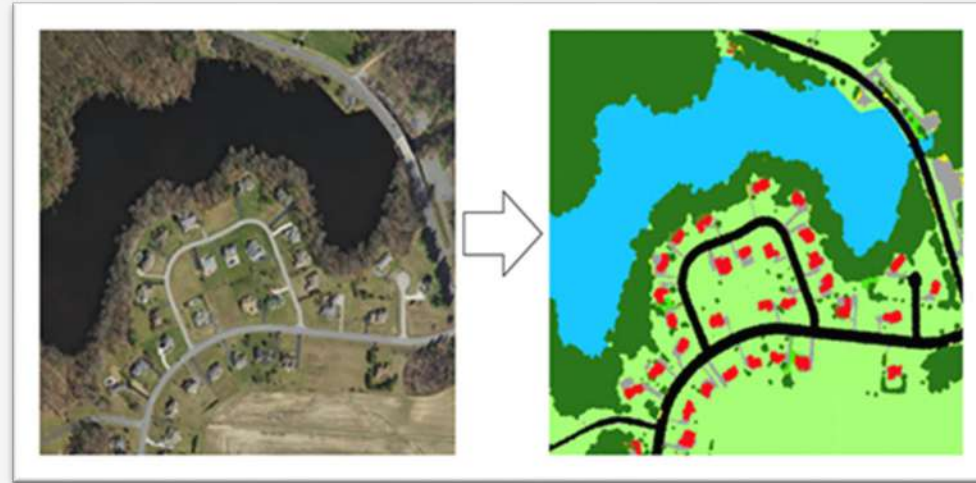
# Pixel-based Classification

Single Image  
or  
Multiple Images

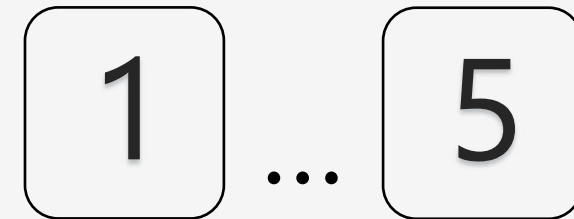




# Feature Selection

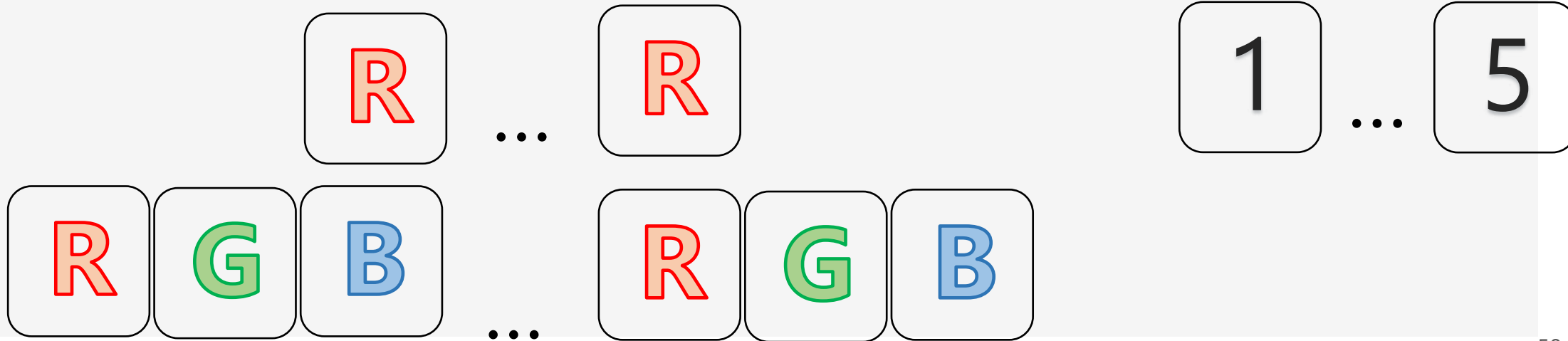
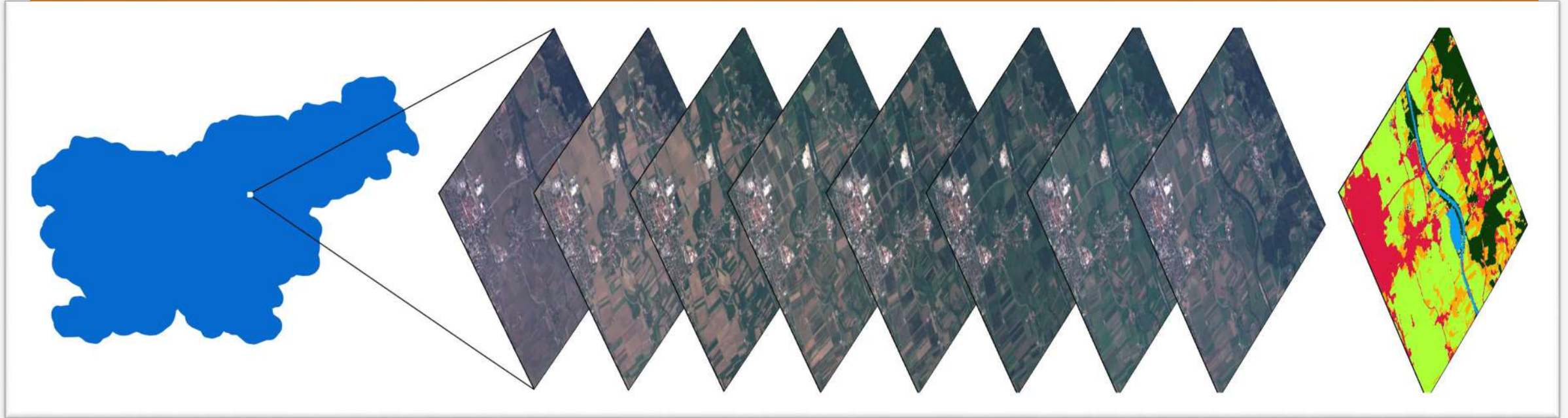


Three Bands



Labels





Thanks !