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Mini-course @ WORCAP 2021

Deep Learning applied for Remote Sensing images

TREES
TRopical Ecosystems and Environmental Sciences lab

RSATE
REMOTE SENSING APPLIED TO TROPICAL ENVIRONMENTS

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Post-doc Researcher - INPE

15 Sep 2021

Learning objectives

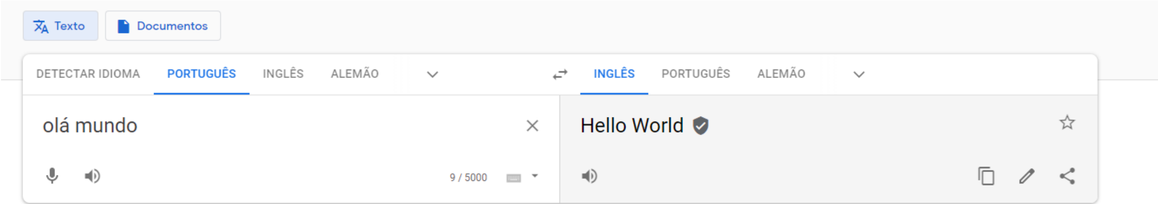
- Describe what is deep learning
- Explain the innovation brought by convolutional neural networks (CNN)
- Identify the main steps on applying CNN for remote sensing
- Apply an example of CNN with test dataset

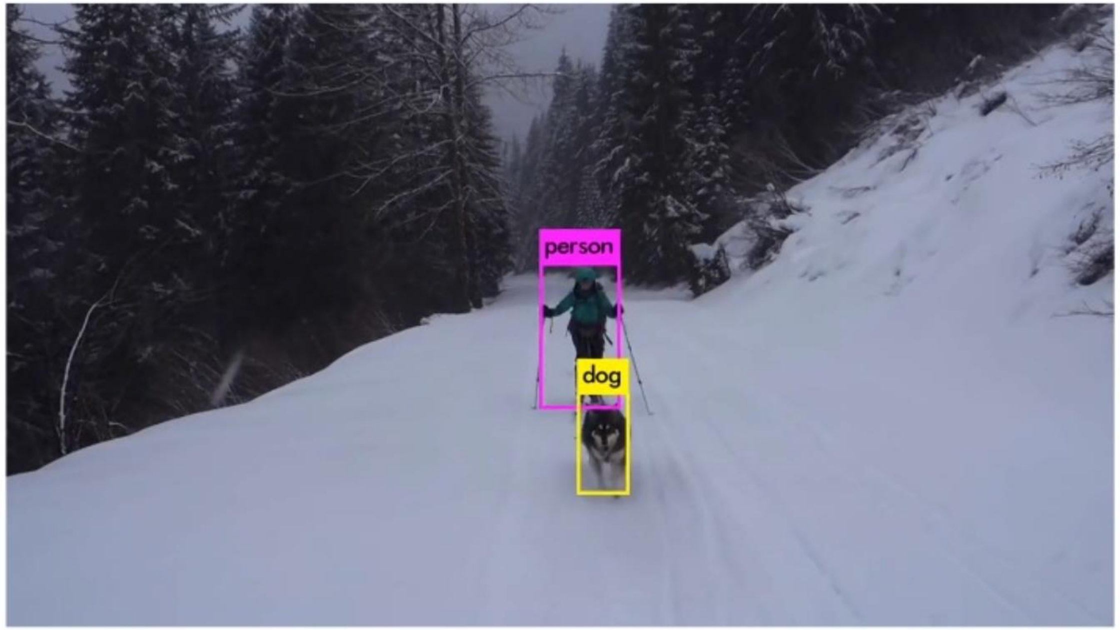
Content

- Lecture - basic concepts
- R and Google Colab

"AI is the new electricity" - Andrew Ng

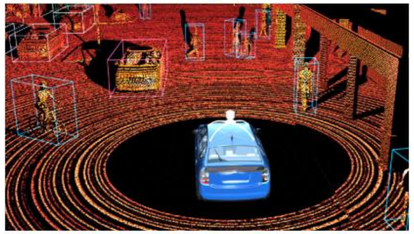
OpenAI Five: Dota2
The International 2018





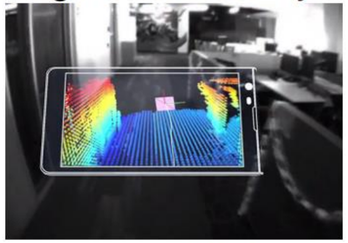
YOLO
https://pjreddie.com/darknet/yolo

Robot Perception



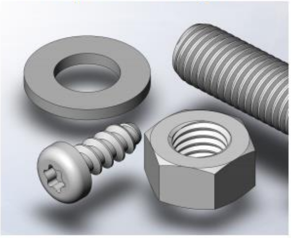
source: Scott J Grunewald

Augmented Reality



source: Google Tango

Shape Design



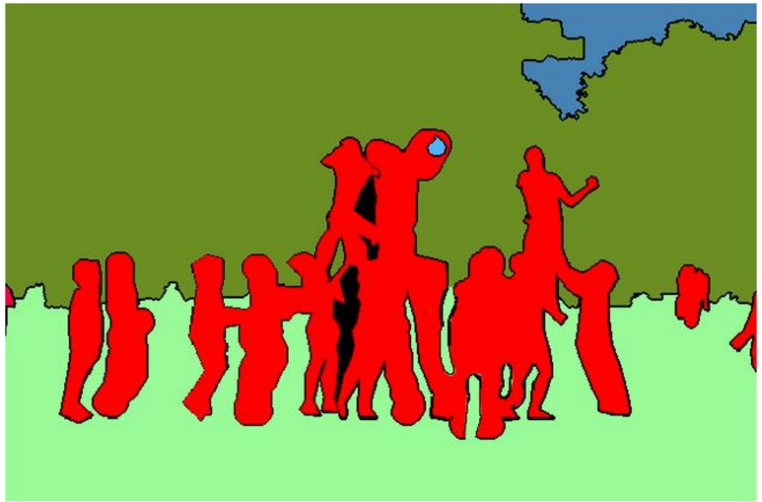
source: solidsolutions

Classification vs Detection vs Semantic vs Instance segmentation

Image Classification

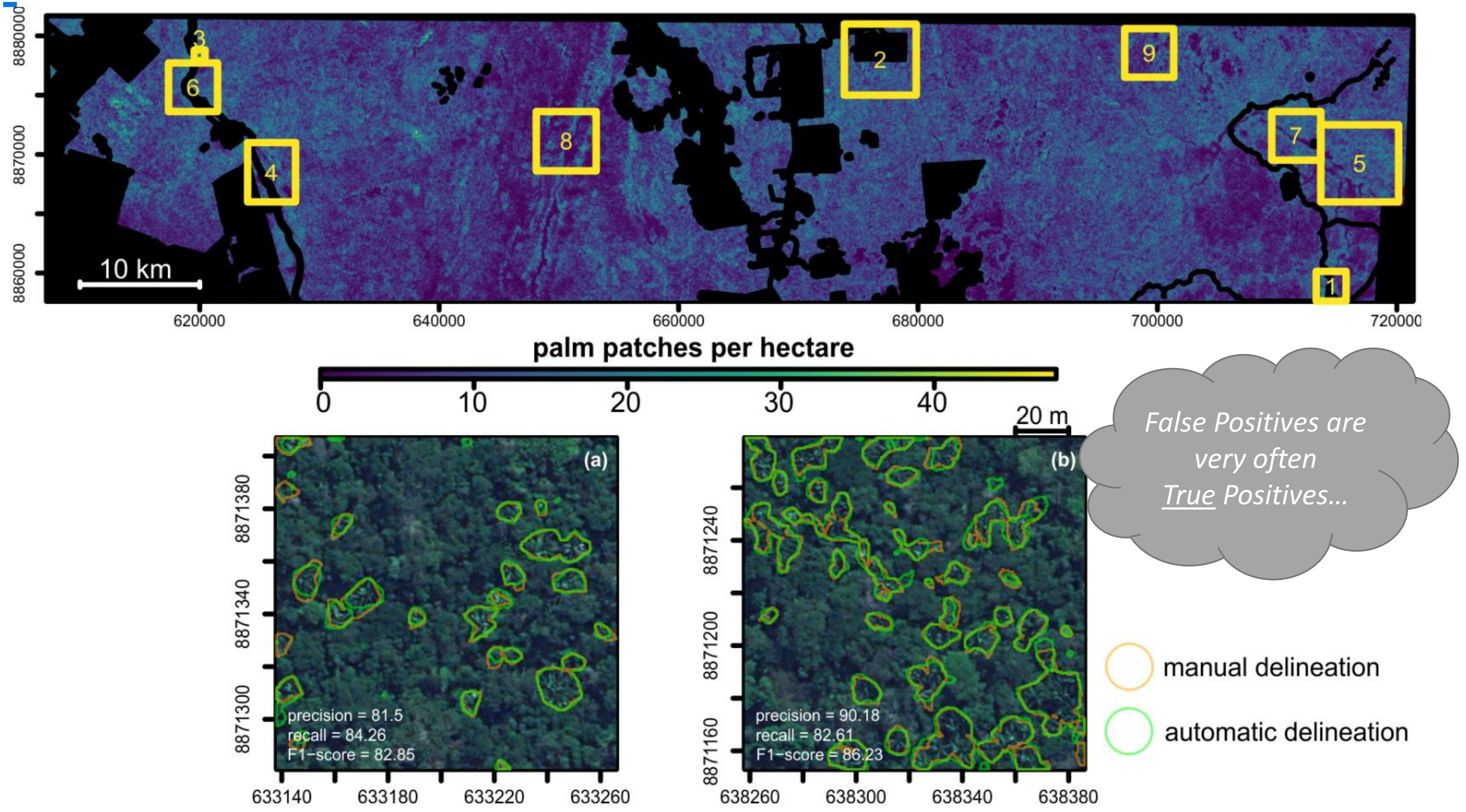
Object Detection

Semantic Segmentation



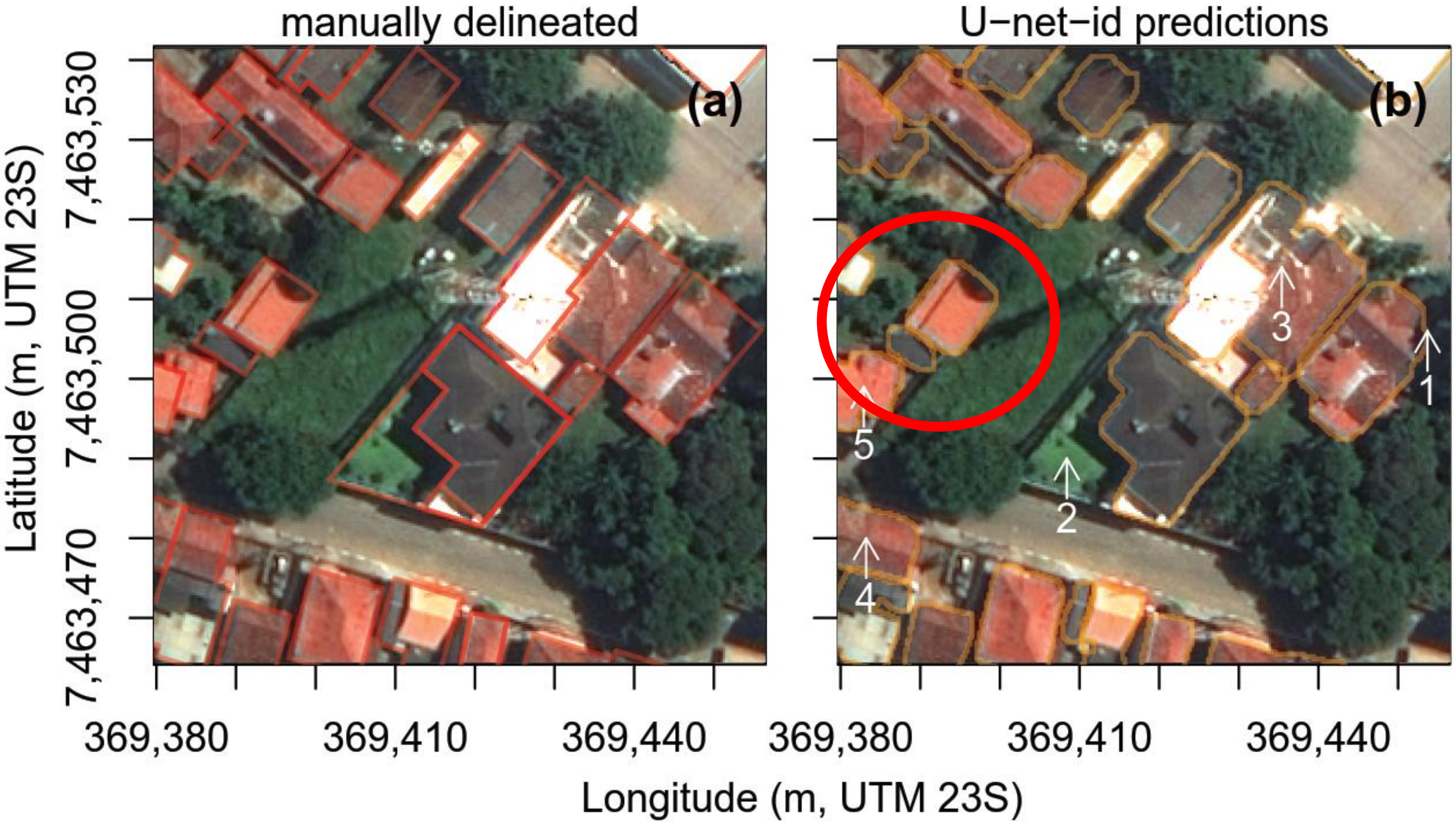
Instance Segmentation

Source: https://becominghuman.ai/what-is-semantic-segmentation-instance-segmentation-panoramic-segmentation-3bbb03856c12



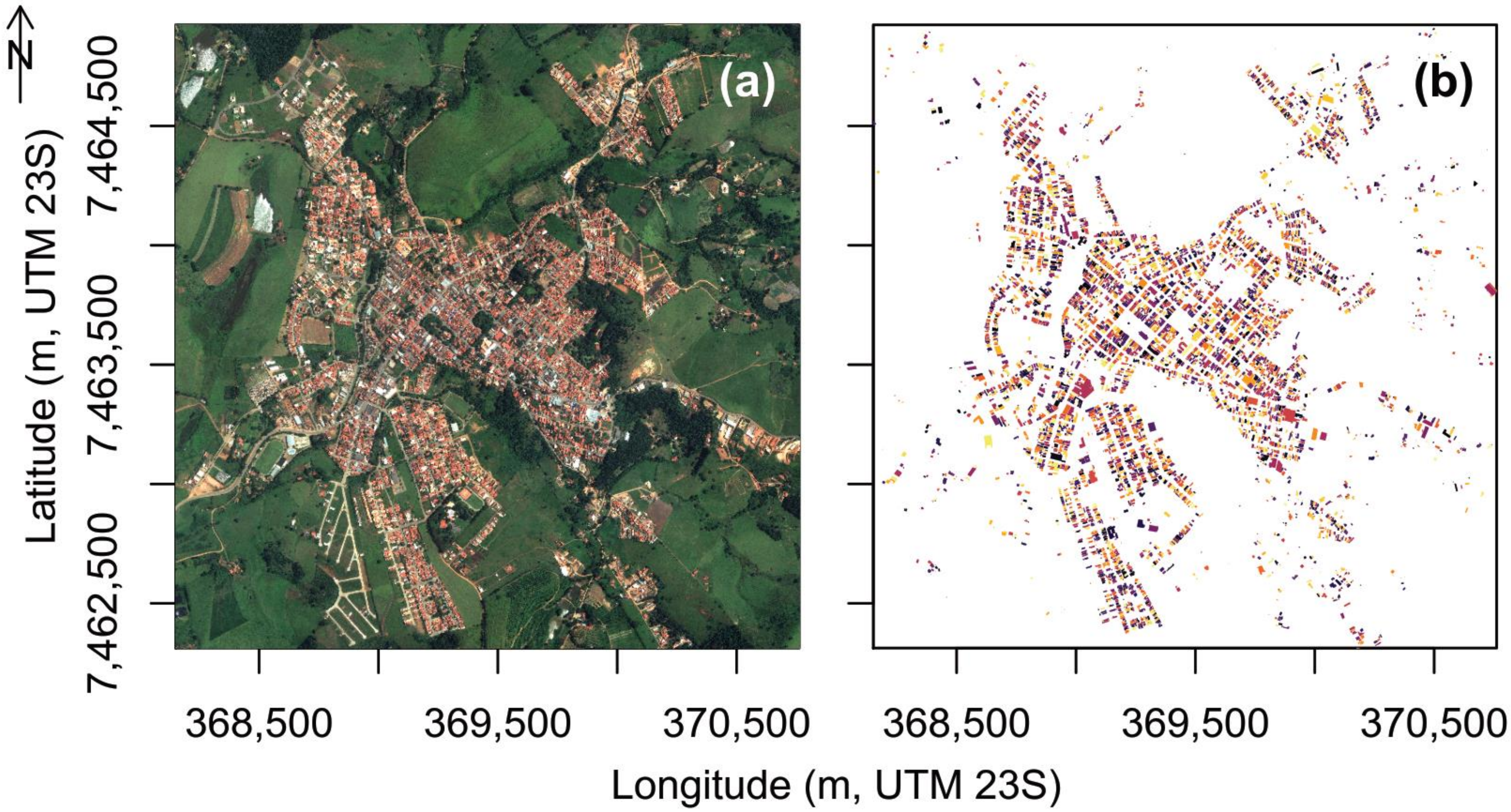
(Wagner et al., 2020, *RS*)

Building segmentation (Wagner et al. 2020)



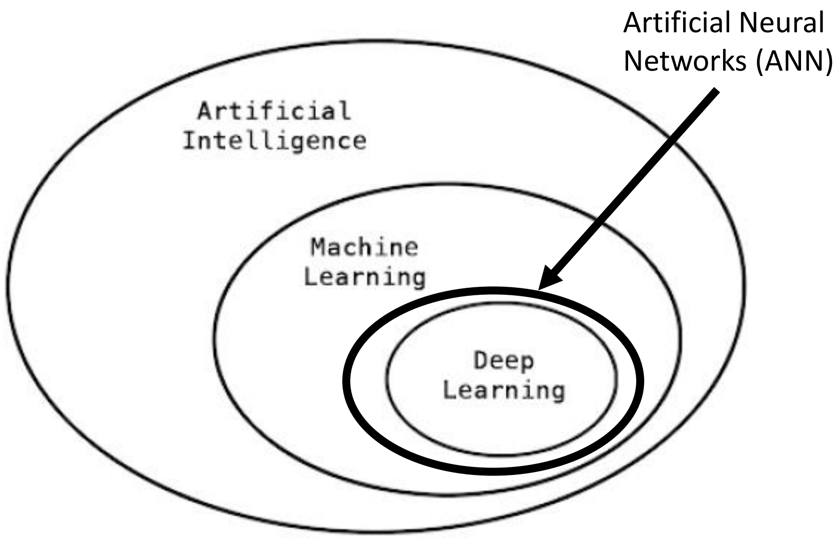
https://www.mdpi.com/2072-4292/12/10/1544

Building segmentation (Wagner et al. 2020)

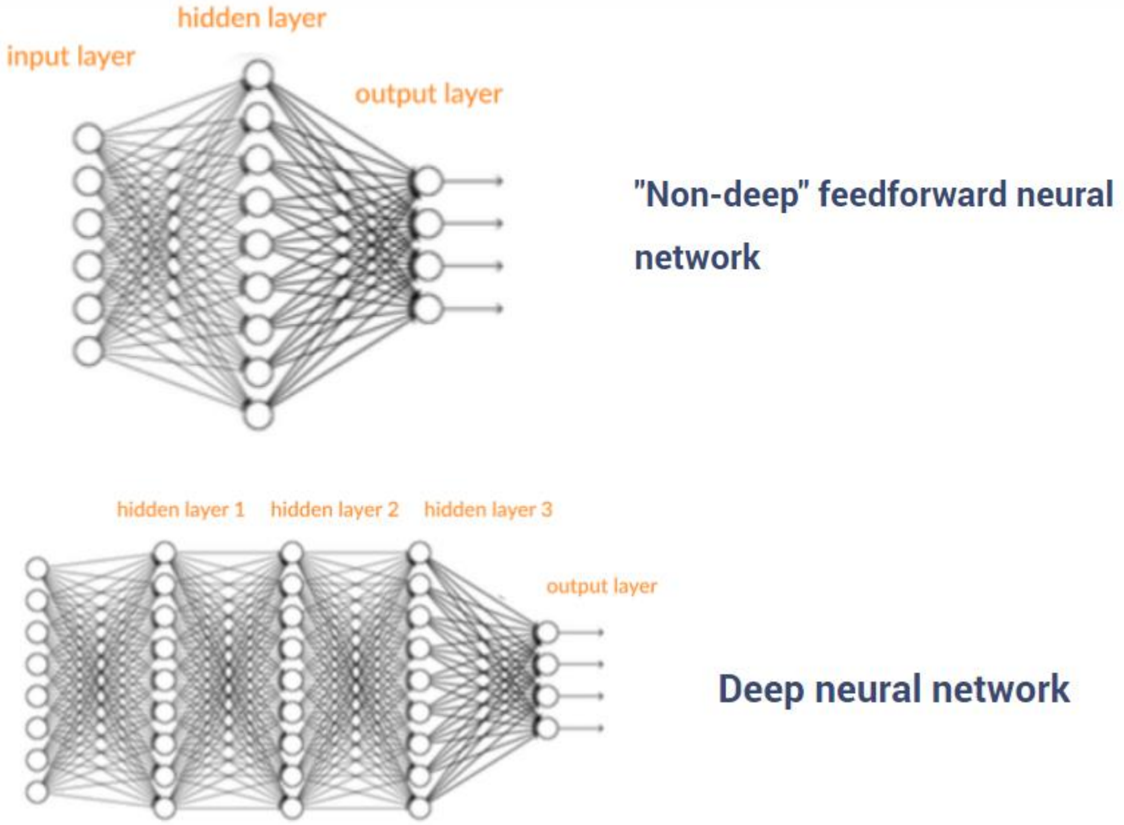


https://www.mdpi.com/2072-4292/12/10/1544

AI -> ML -> ANN -> DL



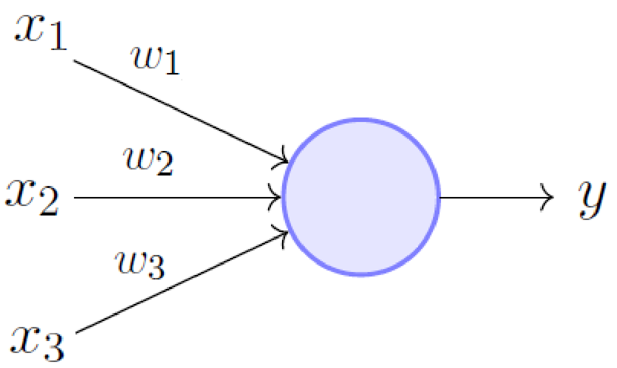
(Adapted from Chollet & Allaire 2017)



Source: http://missinglink.ai/guides/neural-network-concepts/7-types-neural-network-activation-functions-right/

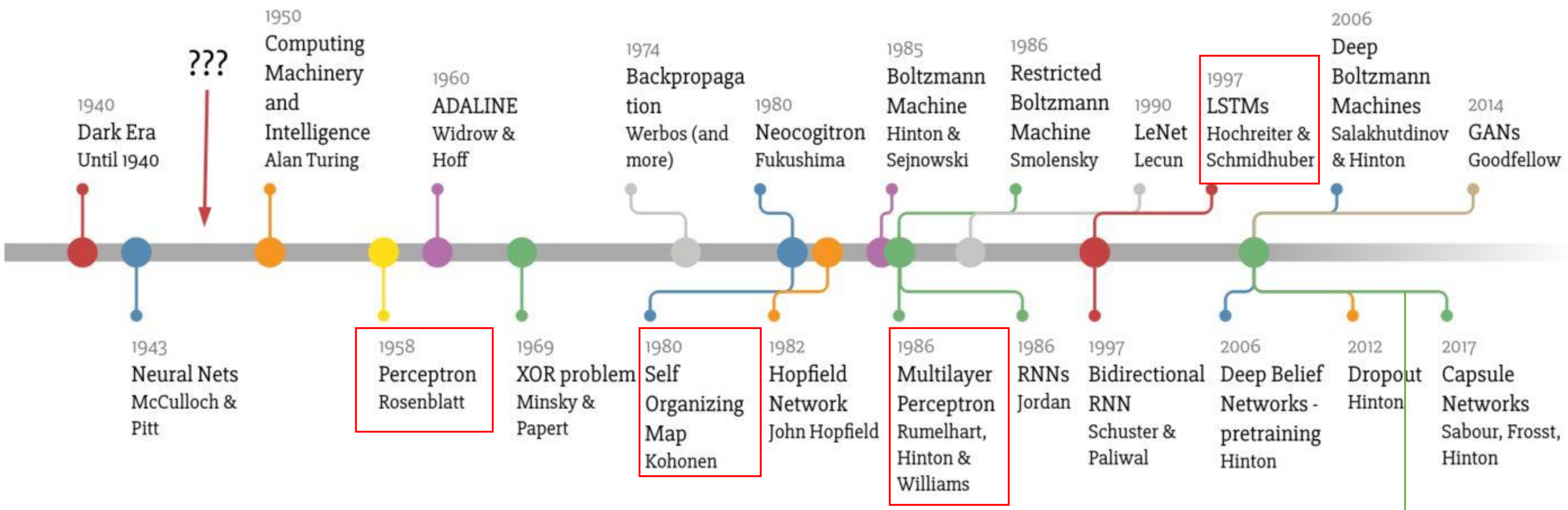
Neural networks

- Goal: approximate some mathematical function
- Relate inputs (x) to outputs (y) using weights (w) in between neurons
- Can have many layers with neurons
- Applications for regression or classification problems
- Usually supervised but can also be unsupervised



Perceptron Model (Minsky-Papert in 1969)

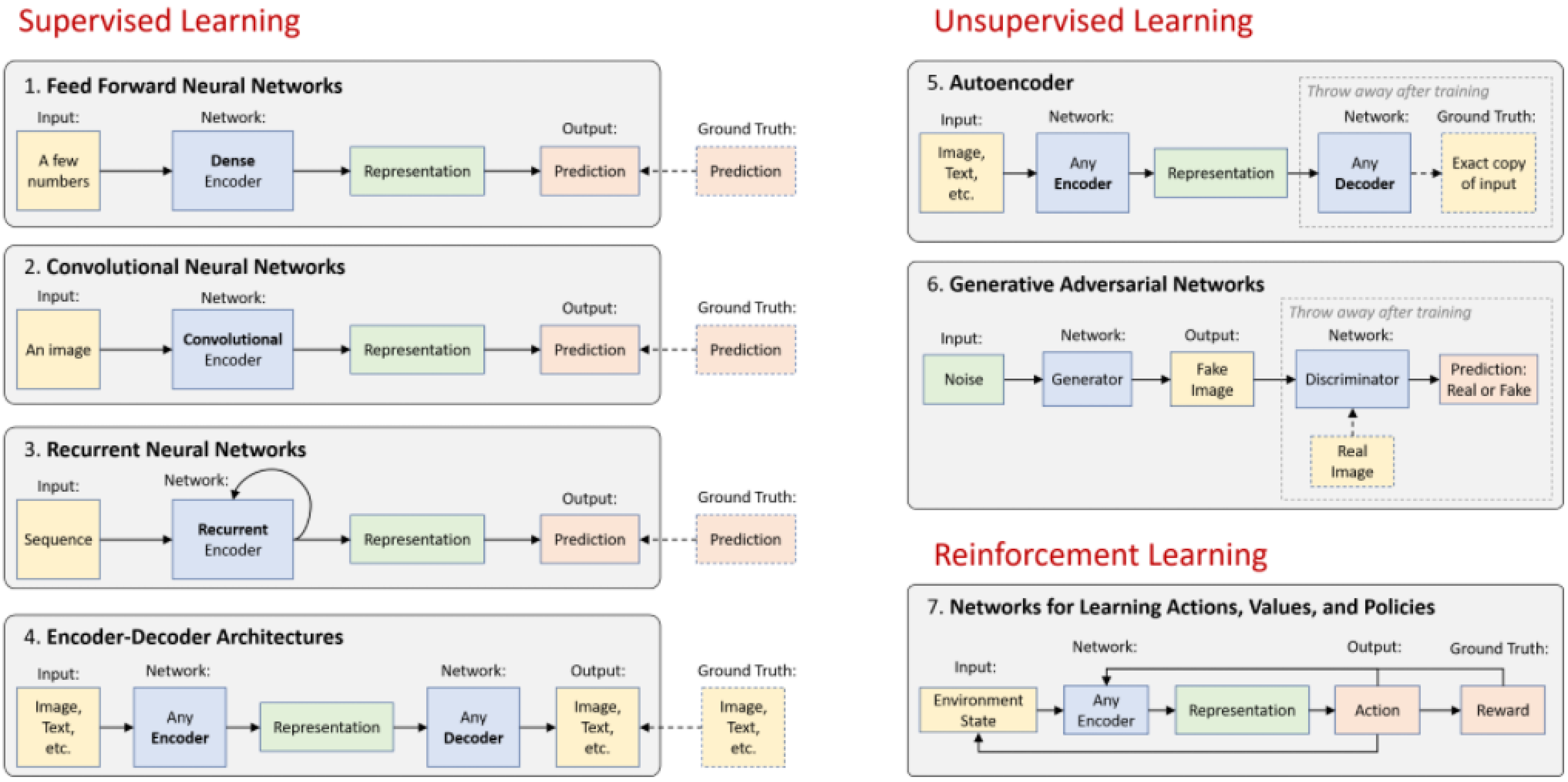
Deep Learning Timeline



Made by Favio Vázquez

CNNs (2012?)
U-Net (2014)

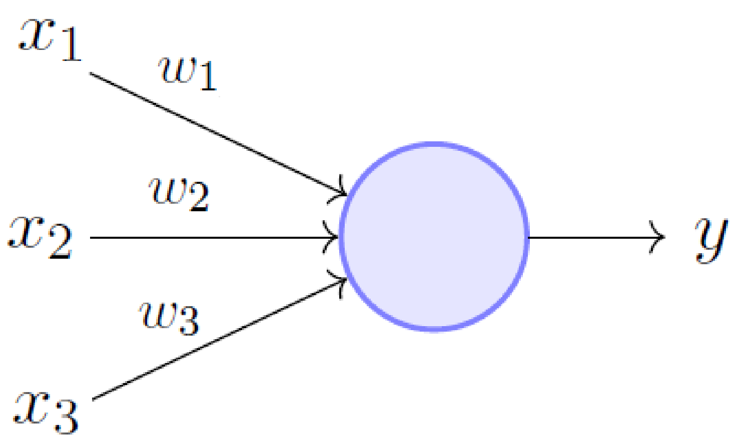
Main DL model types



https://colab.research.google.com/drive/1_g2wLgVSyQjZiDqKaXYKyY7gVWLjbxvM?usp=sharing#scrollTo=Fv0zVXVUQWlZ

Quick intro into ANN - Perceptron 1958

- Basically a linear model
- *feed forward* type
- Weights (w) are adjusted and multiplied by inputs (x) to obtain the output (y)

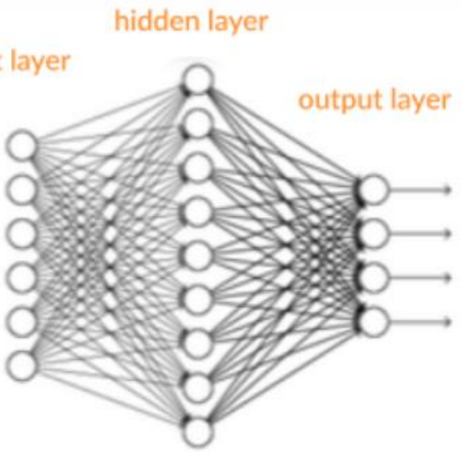


Perceptron Model (Minsky-Papert in 1969)

Simplifying to:

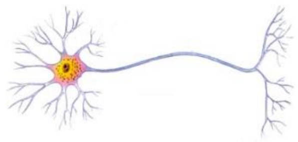
y = x1*w1 + x2*w2 + x3*w3

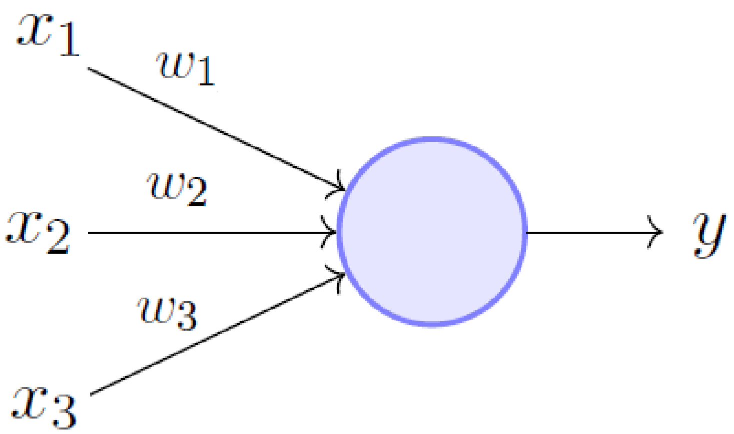
Perceptron 1958



Multi-Layer Perceptron (MLP)
1986

- Basically a linear model
- *feed forward* type
- Weights (w) are adjusted and multiplied by inputs (x) to obtain the output (y)





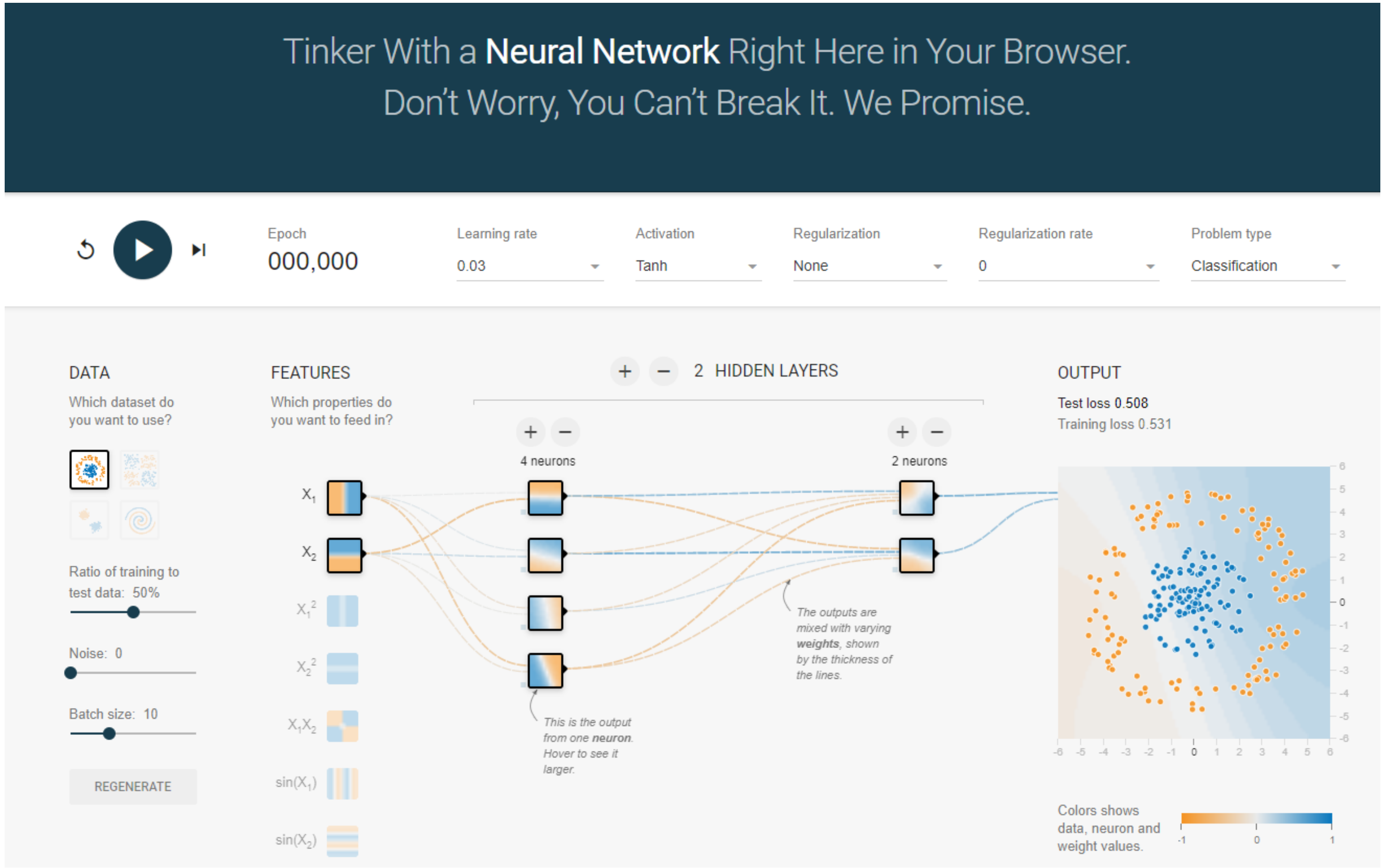
Perceptron Model (Minsky-Papert in 1969)

Simplifying to:

y = x1*w1 + x2*w2 + x3*w3

Playing with a MLP

- https://playground.tensorflow.org/



Why deep learning for remote sensing?

- Classification and segmentation, but also regression

>	Past
Method	• Multi-layer Perceptron (MLP)
Number of layers	• A few, e.g. usually < 5
Accuracy	• Similar accuracy to traditional machine learning algorithms
Domain	• Pixel-level (or region)

Why deep learning for remote sensing?

- Classification and segmentation, but also regression

>	Past	Present
Method	• Multi-layer Perceptron (MLP)	• Convolutional Neural Networks (CNN)
Number of layers	• A few, e.g. usually < 5	• Many and growing, e.g. >20
Accuracy	• Similar accuracy to traditional machine learning algorithms	• <u>Above traditional machine learning methods and close to human level</u>
Domain	• Pixel-level (or region)	• Patch-level

Convolutional neural networks: state-of-the-art methods for semantic segmentation

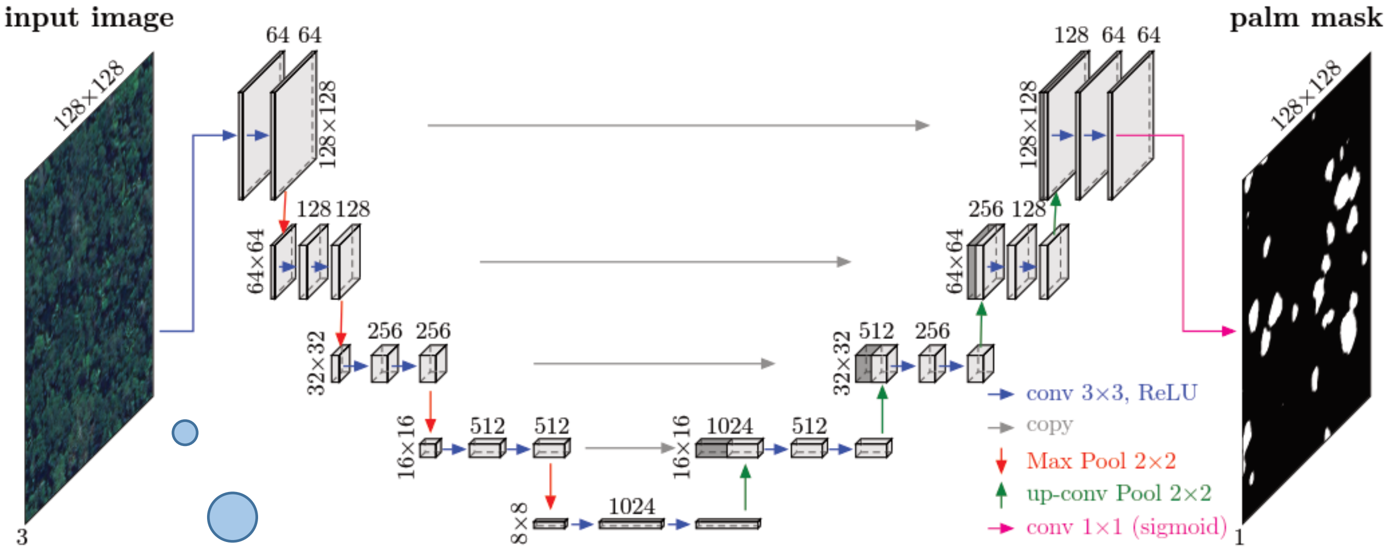


Figure 2. U-net architecture used for canopy palm segmentation, adapted from [19]. The number of channels and the row × column size in pixels are indicated for each cuboid.

One of the most known method is the:
U-Net architecture

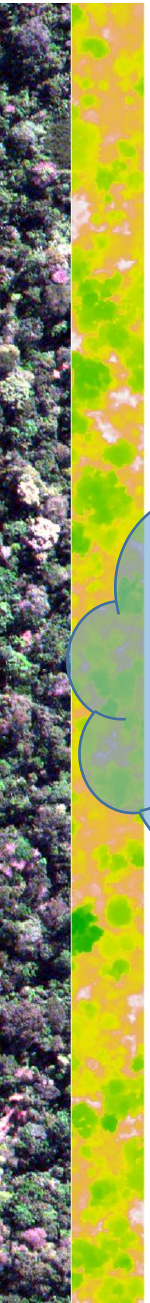
The inputs are image patches instead of pixels

remote sensing
MDPI

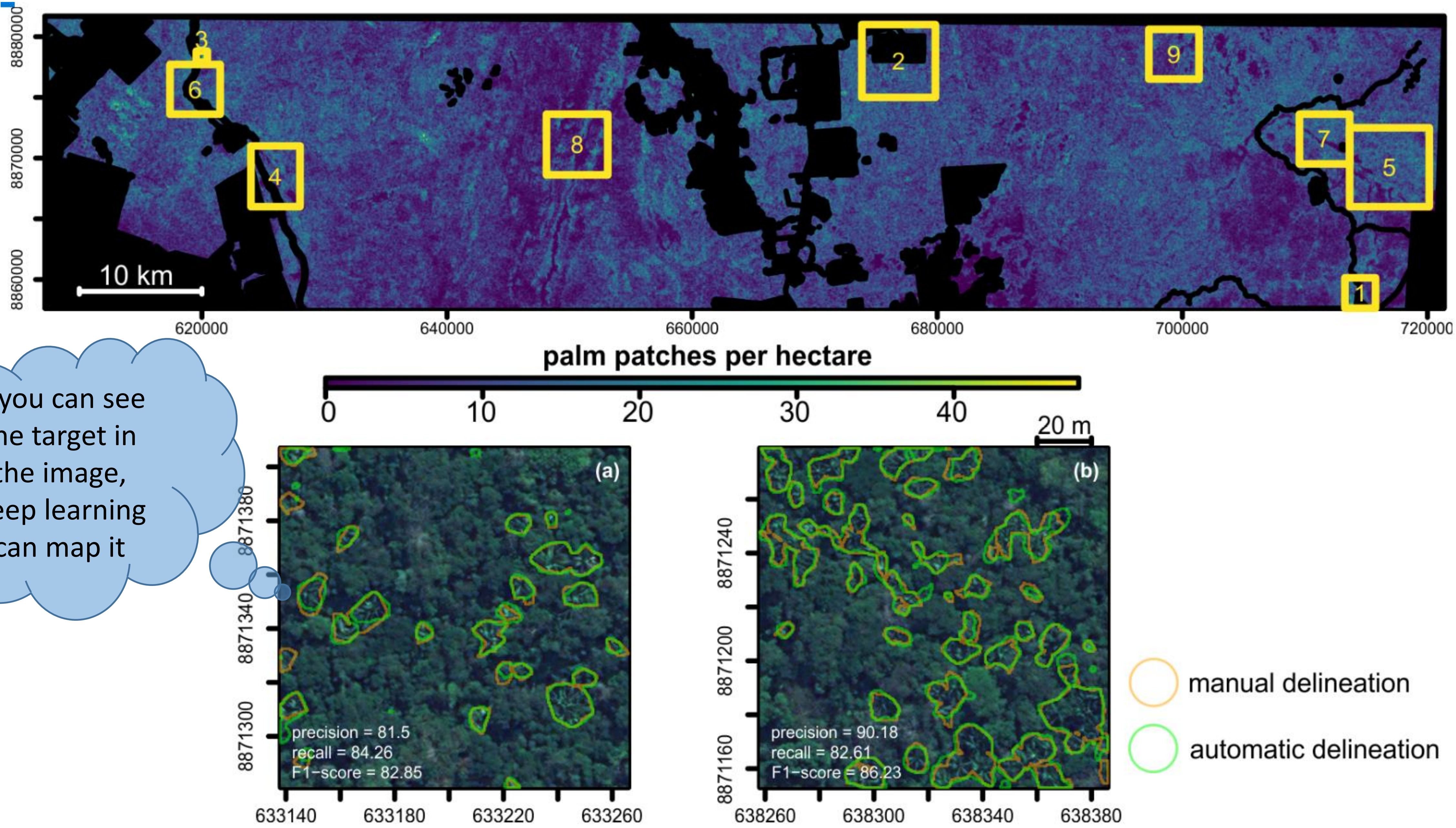
Article

Regional Mapping and Spatial Distribution Analysis of Canopy Palms in an Amazon Forest Using Deep Learning and VHR Images

Fabien H. Wagner [1,*], Ricardo Dalagnol [2], Ximena Tagle Casapia [3,4], Annia S. Streher [2], Oliver L. Phillips [5], Emanuel Gloor [5] and Luiz E. O. C. Aragão [2,6]

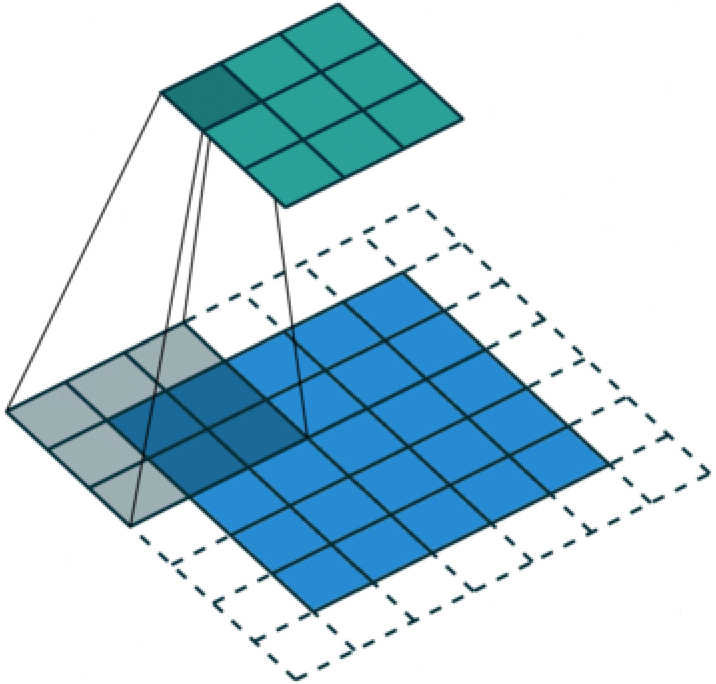


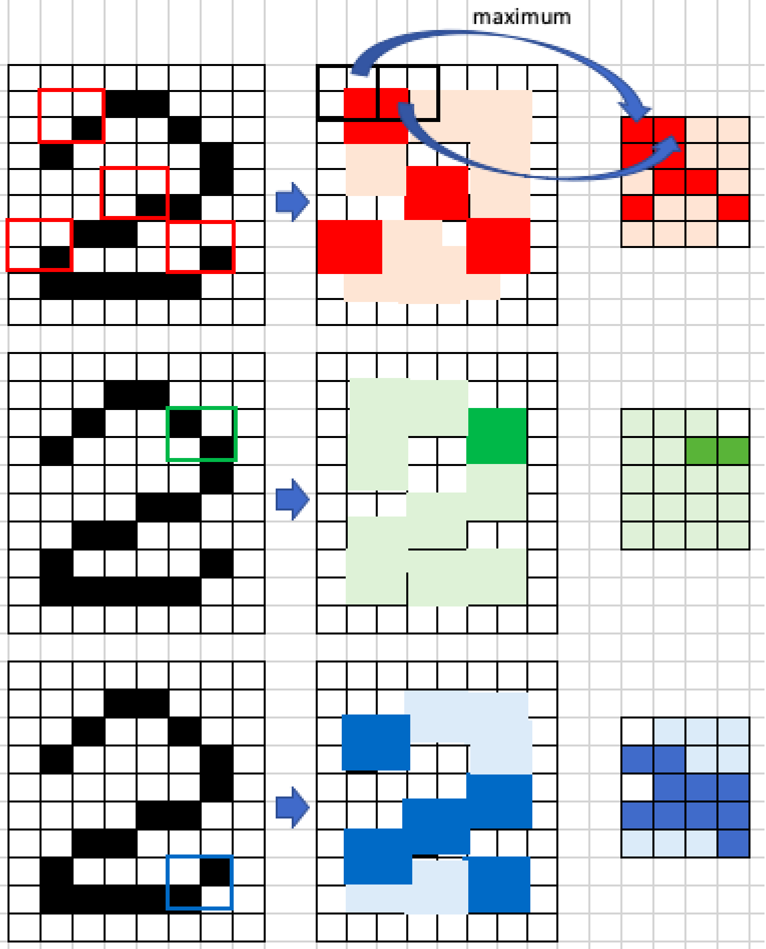
If you can see the target in the image, deep learning can map it



(Wagner et al., 2020, *RS*)

Convolution



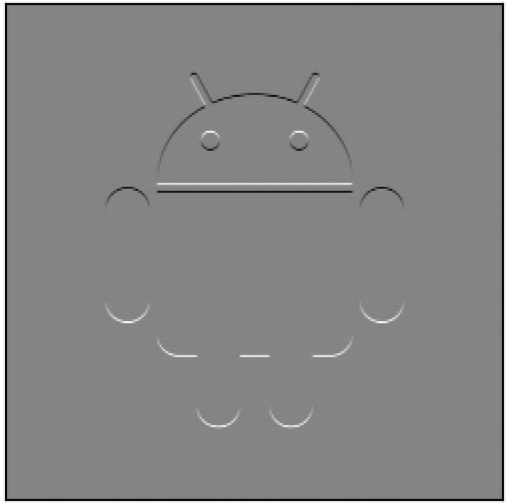


https://towardsdatascience.com/convolutional-autoencoders-for-image-noise-reduction-32fce9fc1763

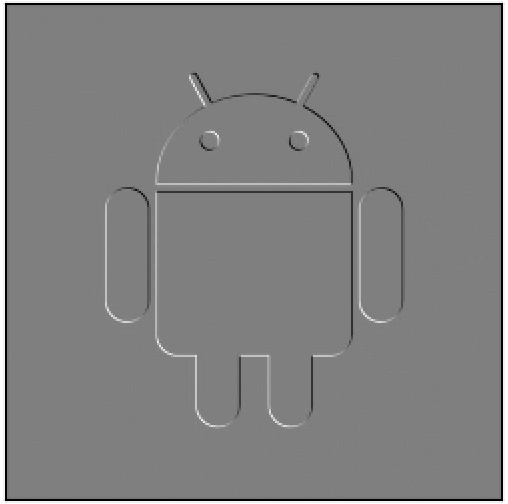
Convolution

-1	-2	-1
0	0	0
1	2	1

Finds horizontals



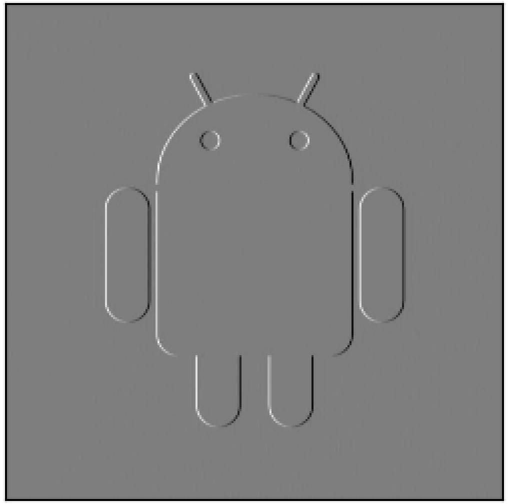
Horizontal Sobel



Combined Sobel

-1	0	1
-2	0	2
-1	0	1

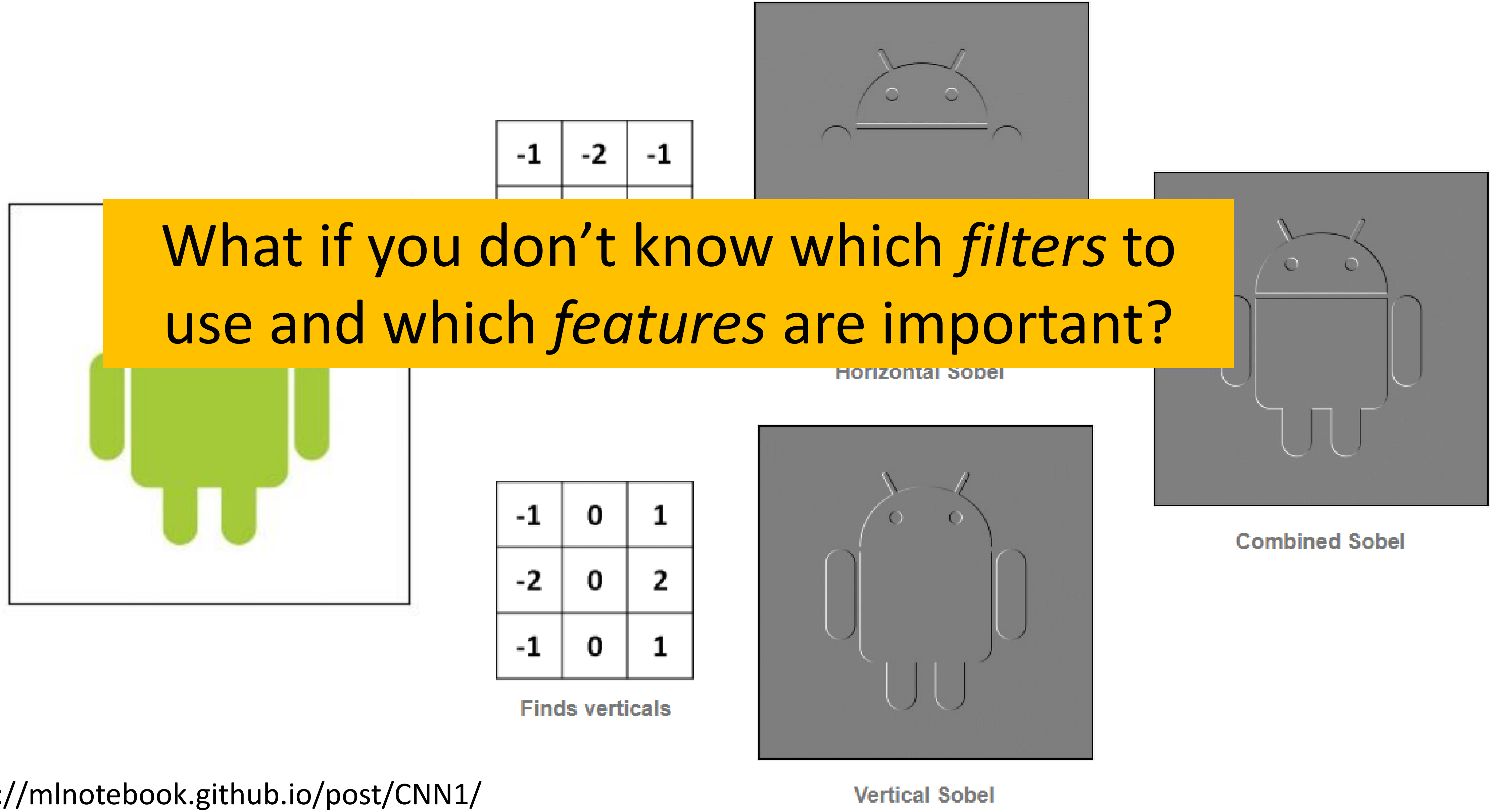
Finds verticals



Vertical Sobel

https://mlnotebook.github.io/post/CNN1/

Convolution



What if you don’t know which *filters* to use and which *features* are important?

https://mlnotebook.github.io/post/CNN1/

CNN

Learning the filters is what the convolutional layers do !

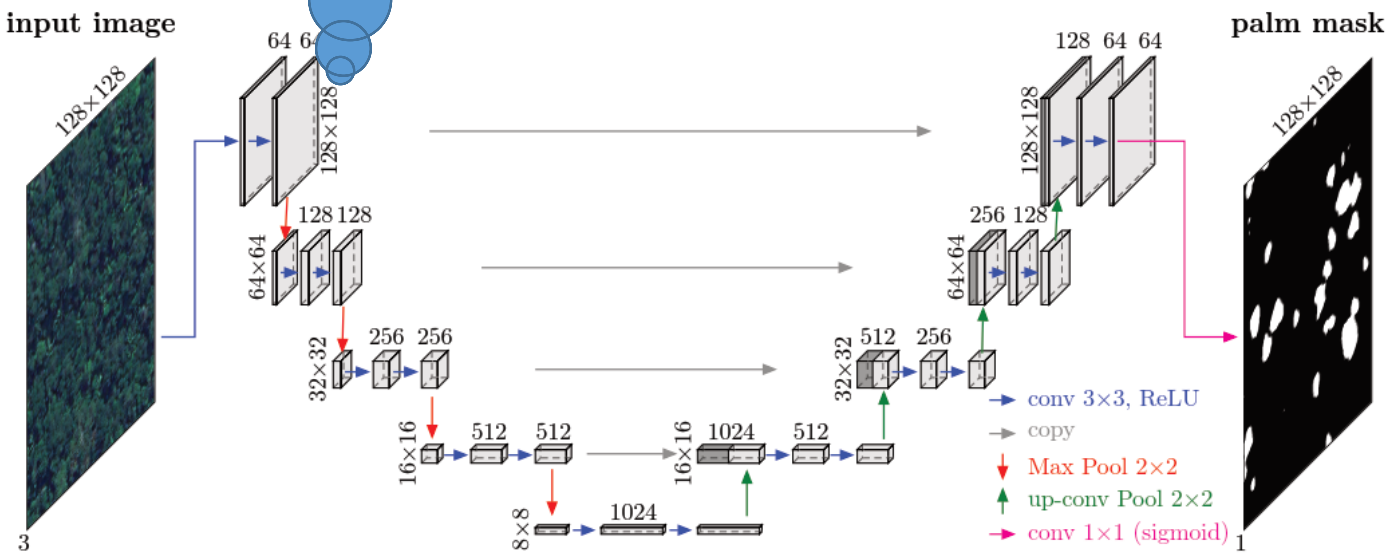
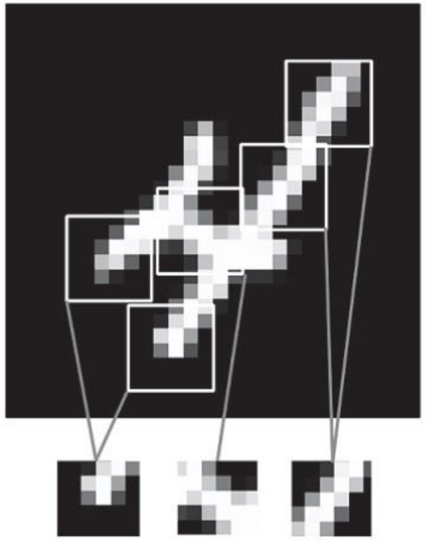
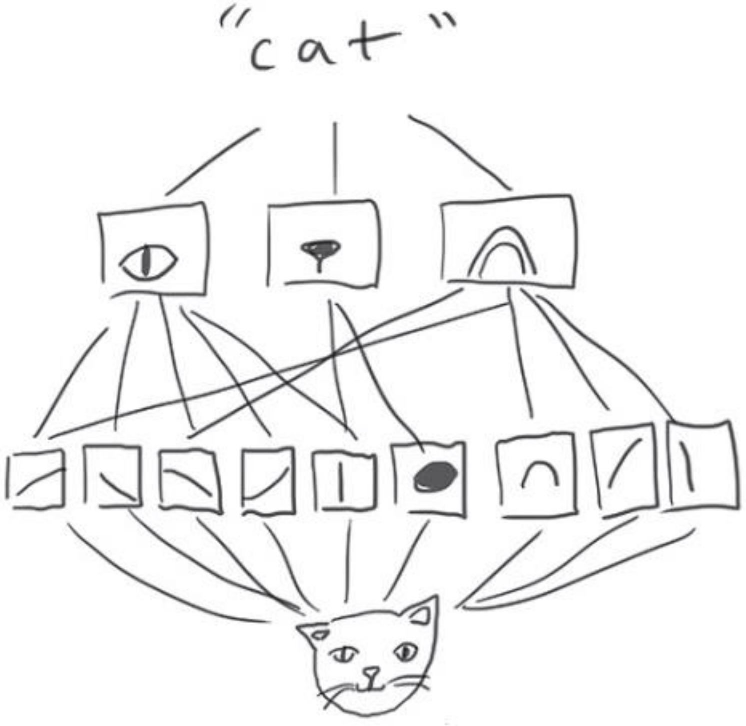


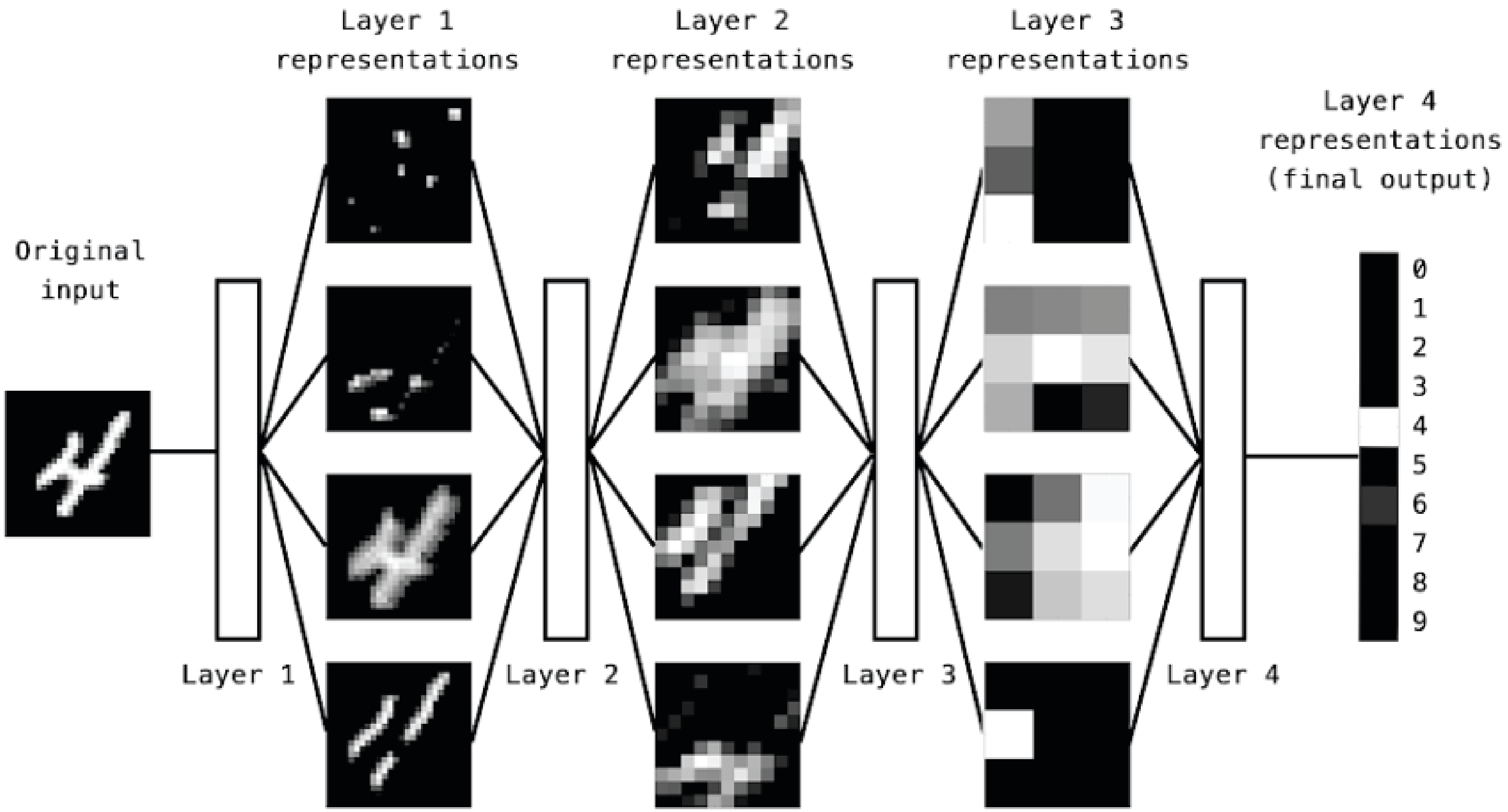
Figure 2. U-net architecture used for canopy palm segmentation, adapted from [19]. The number of channels and the row × column size in pixels are indicated for each cuboid.





(Chollet & Allaire 2017)

Example with *mnist* dataset



(Chollet & Allaire 2017)

Attention for performance metrics

https://towardsdatascience.com/metrics-to-evaluate-your-semantic-segmentation-model-6bcb99639aa2

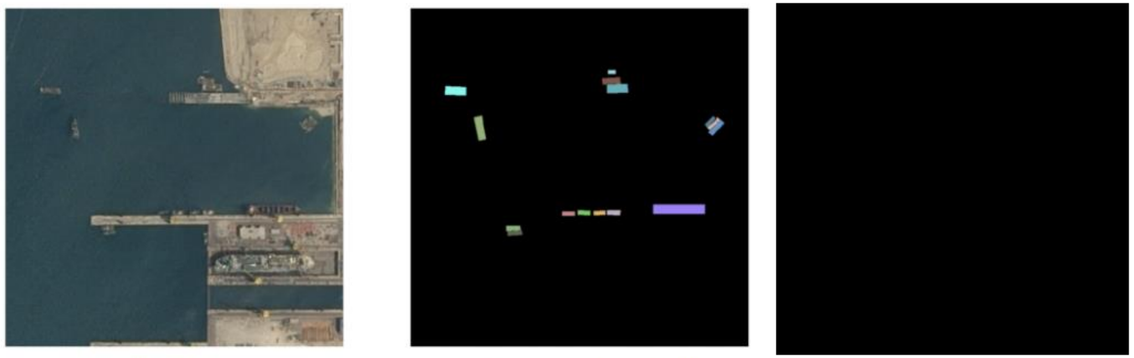
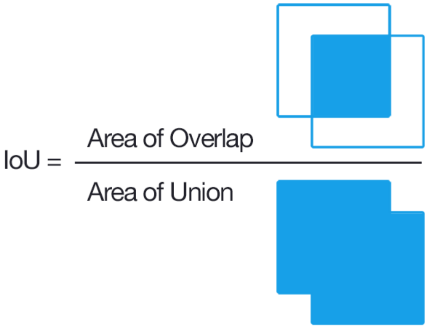


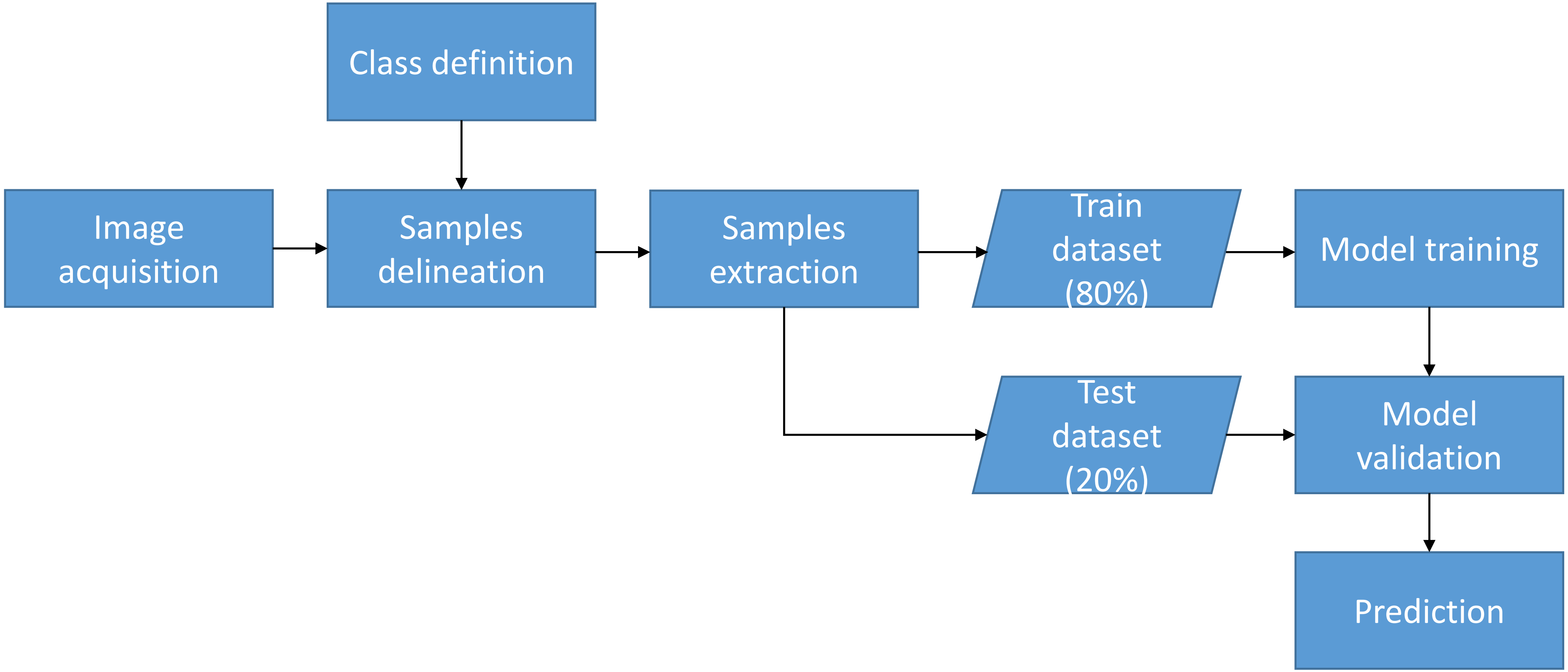
Image from Vlad Shmyhlo in article: Image Segmentation: Kaggle experience (Part 1 of 2) in TDS

- Balanced-classification problems
  - Accuracy, Kappa, etc.
- Class-imbalance
  - Precision, Recall, and F1-score
- Multi-class segmentation
  - Average precision between classes
- Single-class segmentation
  - Intersection over Union (IoU)

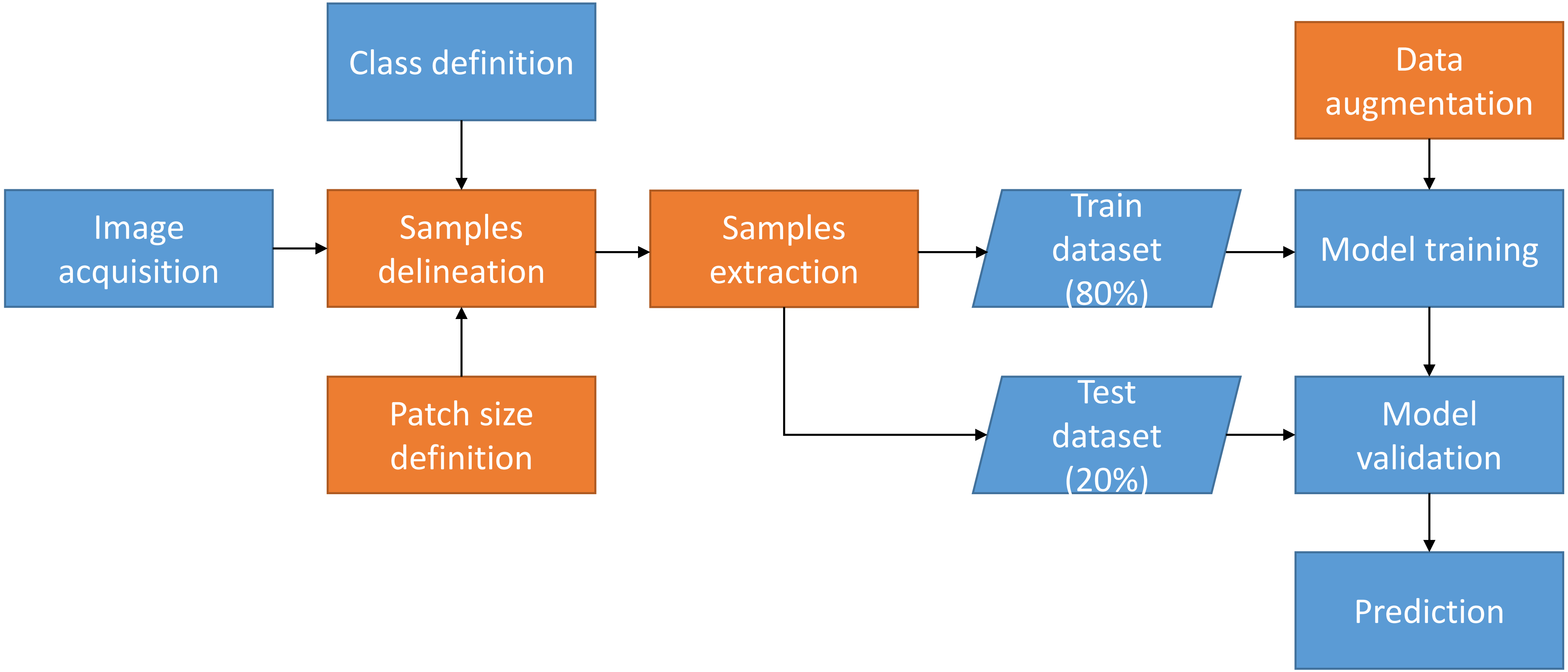


(Chollet & Allaire 2017)

Main steps for RS image segmentation

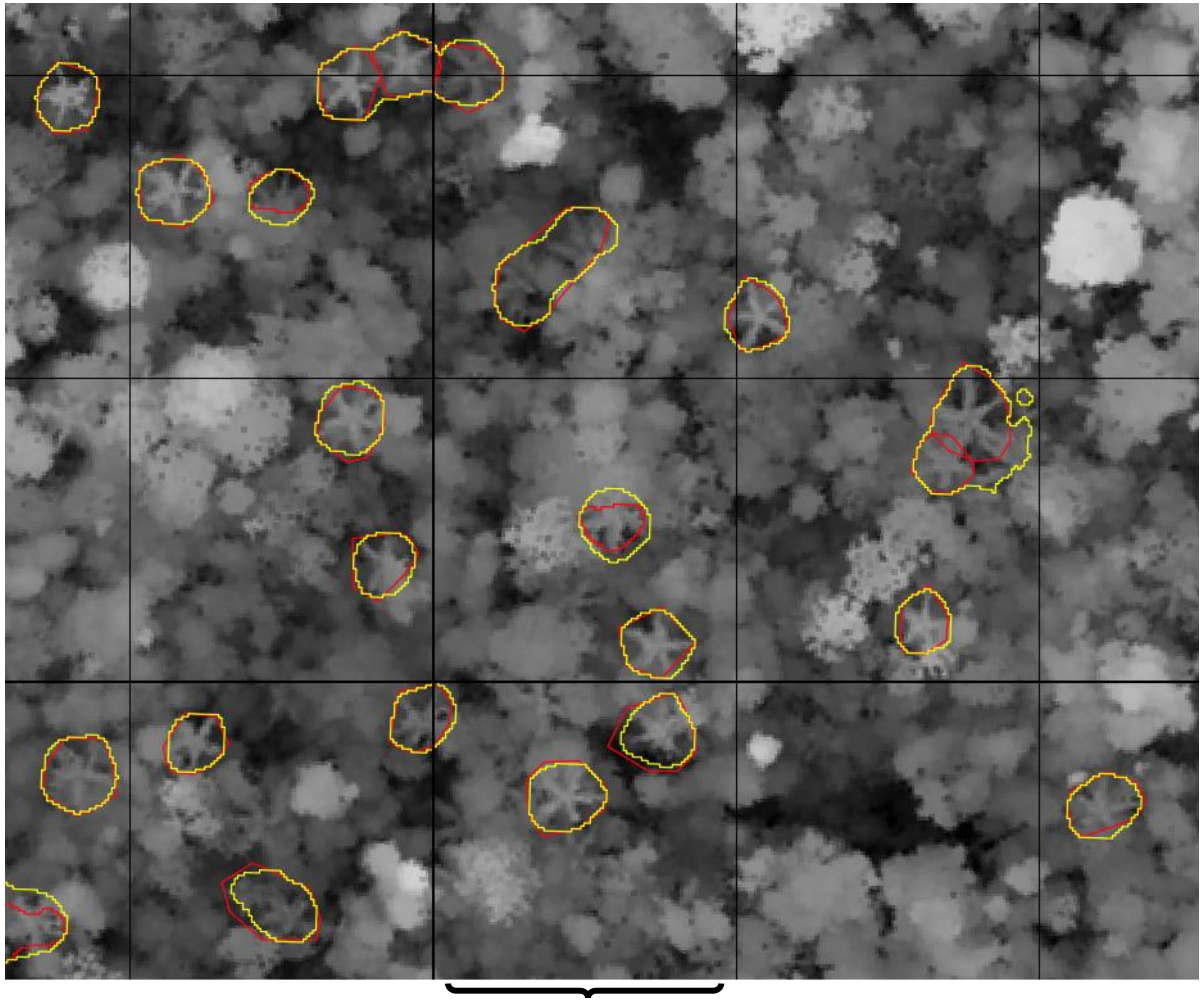


Main steps for RS image segmentation with DL



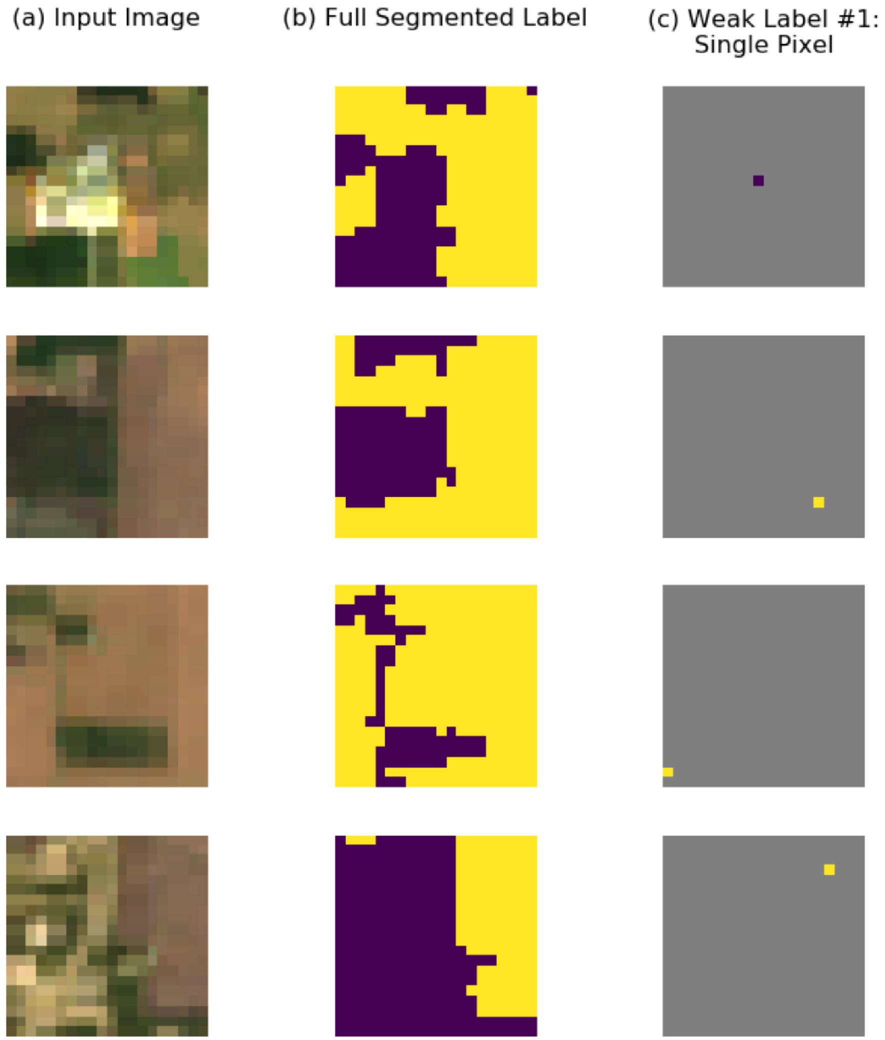
DL vs ML differences: Patch size definition

- Patch of size *m* x *m pixels*
  - *m = multiple of 32*
  - *E.g. 128x128 pixels*
- No optimal definition
- The patch should bring contextual information of the target



64 meters
(128x128 pixels of 0.5m)

DL vs ML differences: Samples delineation



- Samples are usually 'dense'
- Delineated in GIS or other labelling softwares
- Recent research shows ways to use single pixels called 'weak supervised learning' (Wang et al., 2020)

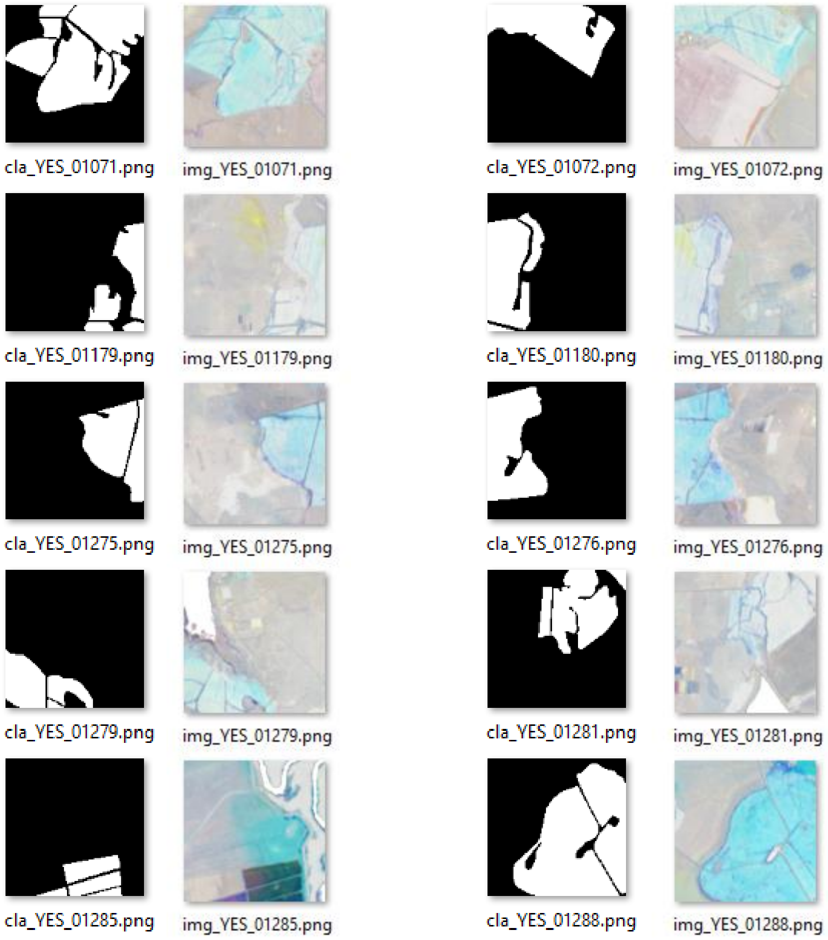
Wang et al., 2020 - https://www.mdpi.com/2072-4292/12/2/207/htm

DL vs ML differences: Samples extraction

Traditional ML: pixels to table

	X1	X2	X3	X4	class
2129	0.18409561	0.35243168	0.8963459	0.9284320	Rice
2130	0.18615542	0.48938116	0.9341421	0.9476923	Rice
2131	0.24692002	0.25649321	0.5984405	0.8030888	Rice
2132	0.25300574	0.79422522	0.9033156	0.8696288	Rice
2133	0.30483481	0.69084626	0.9067416	0.9049394	Rice
2134	0.25143707	0.25066489	0.8754706	0.9301759	Rice
2135	0.31929952	0.73389256	0.9191375	0.9151656	Rice
2136	0.44001359	0.47436264	0.4754879	0.4471128	Other
2137	0.62812239	0.60058695	0.4603175	0.4119138	Other
2138	0.66906476	0.59619188	0.5153217	0.4031008	Other
2139	0.51898736	0.56076455	0.2089286	0.2098260	Other
2140	0.47804552	0.37455633	0.3560375	0.3706468	Other
2141	0.57003969	0.56485832	0.5612745	0.6241940	Other

Deep Learning: patches to files

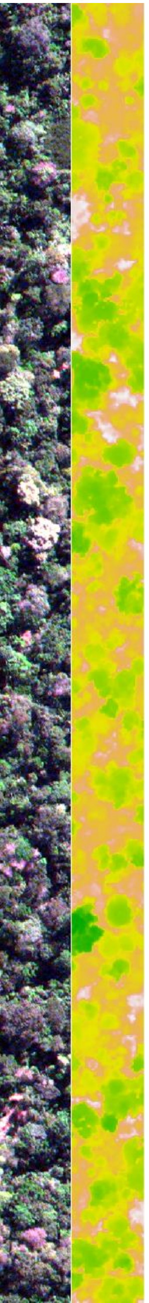


When predicting, we crop, apply model, then mosaic.

DL vs ML differences: Data augmentation

- Randomized processes that introduces variability in the dataset to teach the model that patterns are not limited to certain angles, values, scales, etc.
  - 0-360◦ rotations
  - Horizontal and vertical flips
  - Signal change in brightness and saturation (e.g. 90 to 110%)
  - Zoom

(Chollet & Allaire 2017)



What types of RS data can I use? All types!

Optical

- Coarse to high- resolution
  - MODIS
  - Landsat series
  - CBERS series
- Very high resolution (VHR)
  - WorldView-2
  - Planet imagery
  - UAV (Untripulated Aerial Vehicle)
  - Airborne

SAR

- Sentinel-1
- ALOS PALSAR

Lidar

- UAV or Airborne
  - Canopy Height Model (CHM)
  - Digital Terrain Model (DTM)
  - Point cloud

Individually or combined…
Deep Learning accepts it all ☺

CPU vs GPU

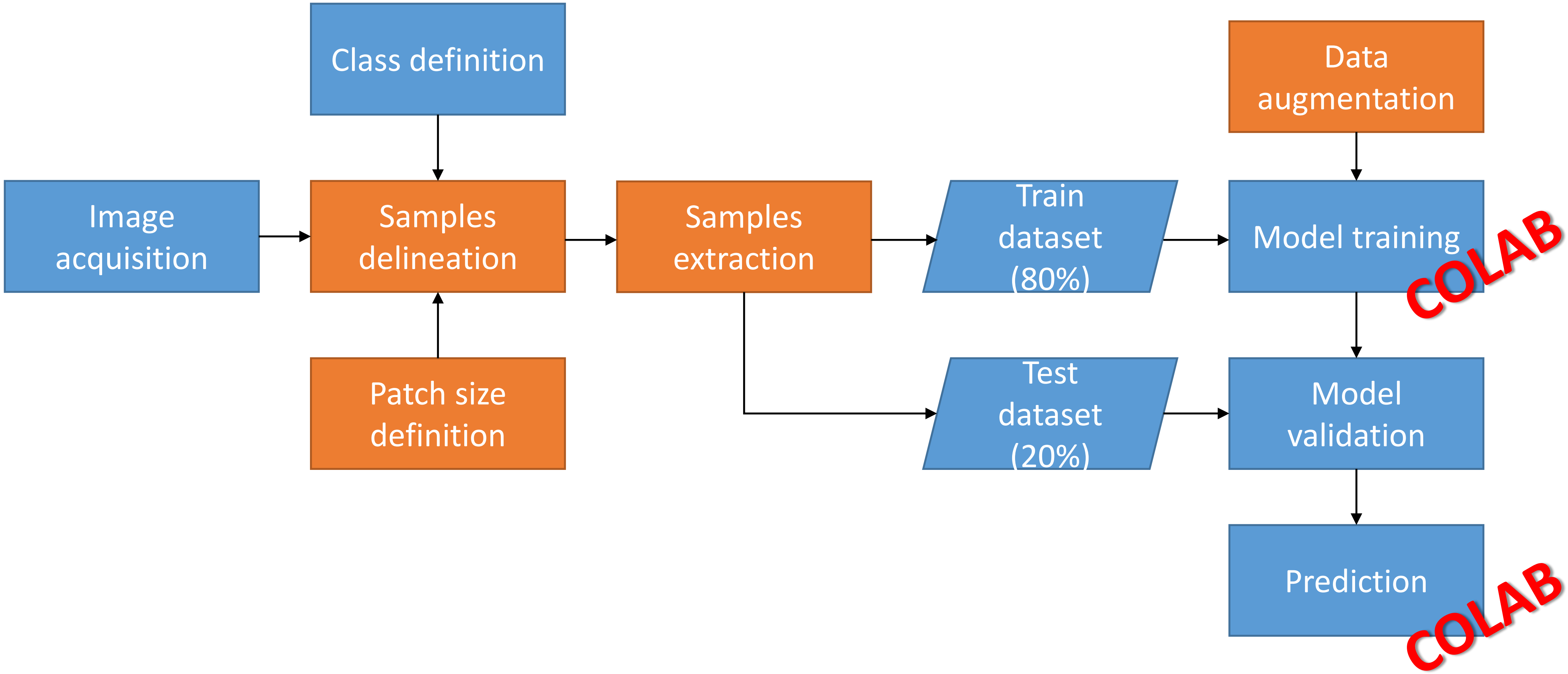
https://www.quora.com/Why-are-GPUs-well-suited-to-deep-learning

Which language and platform to run DL?

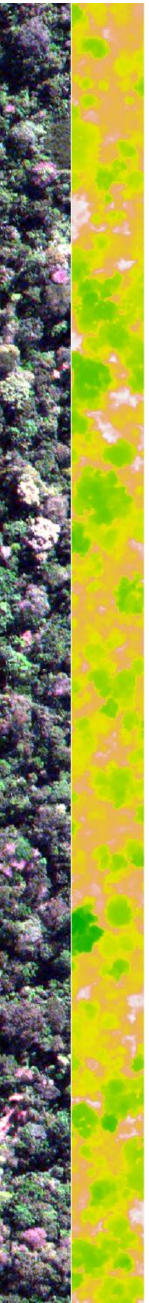
- Python: tensorflow, keras, pytorch
- R: with reticulate / keras <- tensorflow

- Your own computer with GPU
- Google Colab: free, but limited – ideal for beginners
- Paid-virtual machines with GPU (from Amazon, Google, etc.)

Main steps for RS image segmentation with DL



https://doi.org/10.5281/zenodo.3929709



July 3, 2020 Lesson Open Access

Tensorflow and Keras installation steps for Deep Learning applications in Rstudio

Ricardo Dalagnol; Fabien Wagner

Download the PDF file and follow the instructions. This is for NVIDIA GPU and Windows OS.

Contacts : Ricardo Dalagnol (ricds@hotmail.com)

Fabien Wagner (wagner.h.fabien@gmail.com)

v2.0 Updated for Python 3.9 and Tensorflow 2.5.

Send an email for collaboration or if you have suggestions for the improvement of this manual.

Preview

Página: 1 de 4 Zoom automático

Version 2.0 – 13 July 2021

Tensorflow and Keras installation steps for Deep Learning applications in Rstudio

Ricardo Dalagnol[1] and Fabien Wagner

1. Install OSGEO (https://trac.osgeo.org/osgeo4w/) to have GDAL utilities and QGIS. Do not modify the installation path. This is mainly for the remote sensing community, to work with Geotiff.
2. Install ImageMagick (https://imagemagick.org/index.php) for image visualization.
3. Install the latest Miniconda (https://docs.conda.io/en/latest/miniconda.html)
4. Install Visual Studio
   a. Install the 2019 or 2017 free version. The free version is called 'Community'.

Edit

New version

Publication date:
July 3, 2020

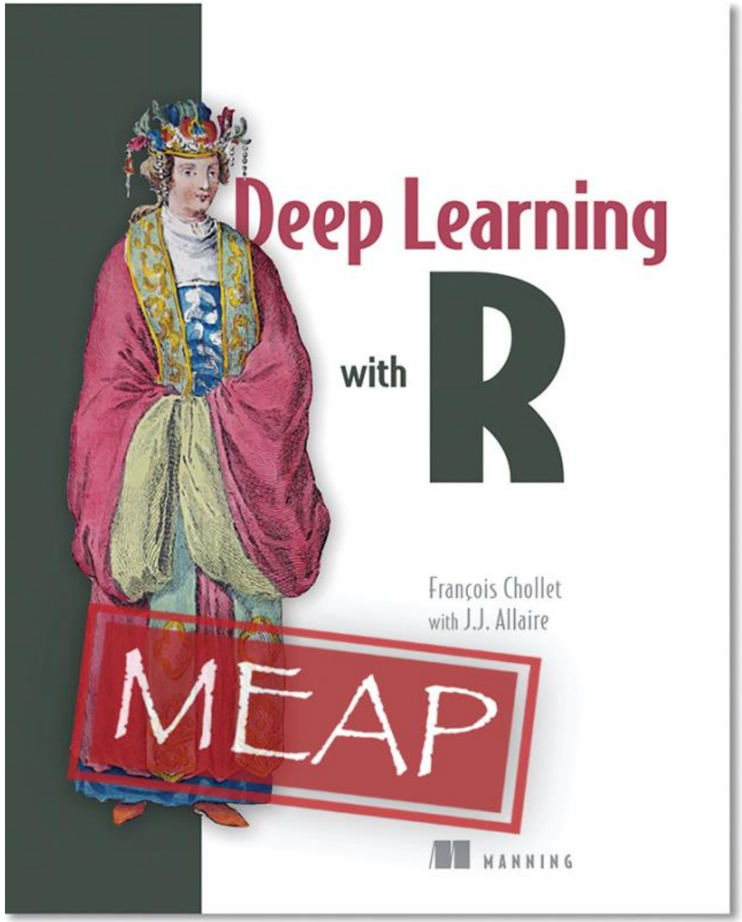
DOI:
DOI 10.5281/zenodo.5095433

Keyword(s):
tensorflow keras rstudio r rstats deep learning unet

Versions

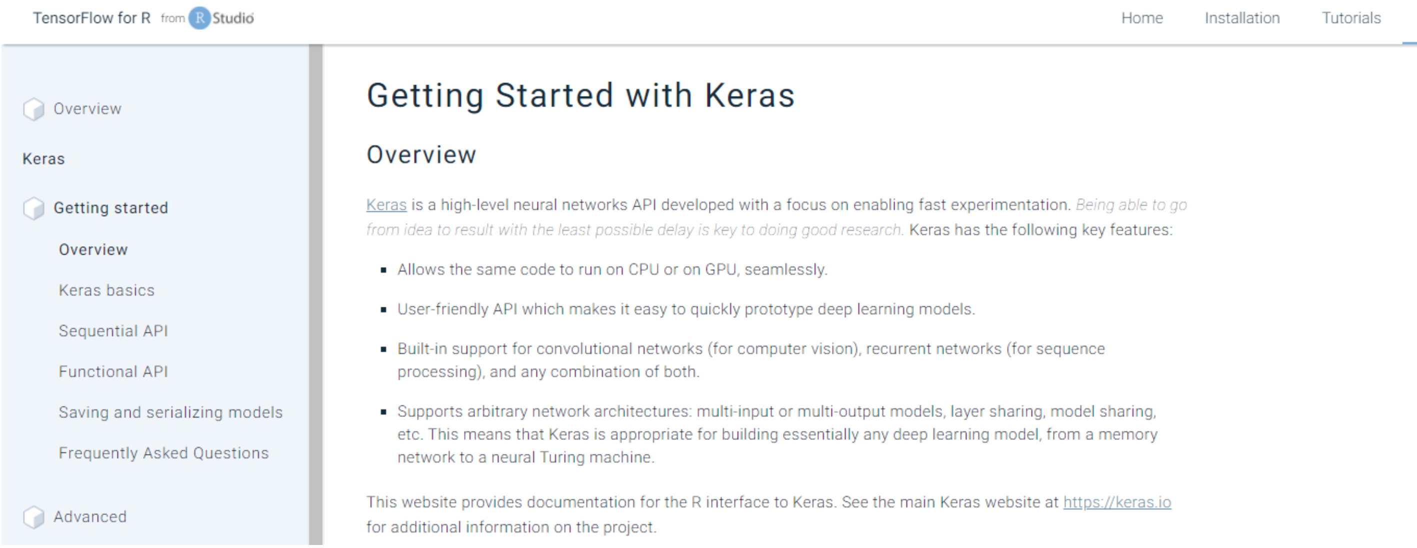
References

"DL Bible"



(Chollet & Allaire 2017)

Examples at https://tensorflow.rstudio.com/guide/keras/


TensorFlow for R from RStudio | Home | Installation | Tutorials

Overview

Keras

Getting started

- Overview
- Keras basics
- Sequential API
- Functional API
- Saving and serializing models
- Frequently Asked Questions

Advanced

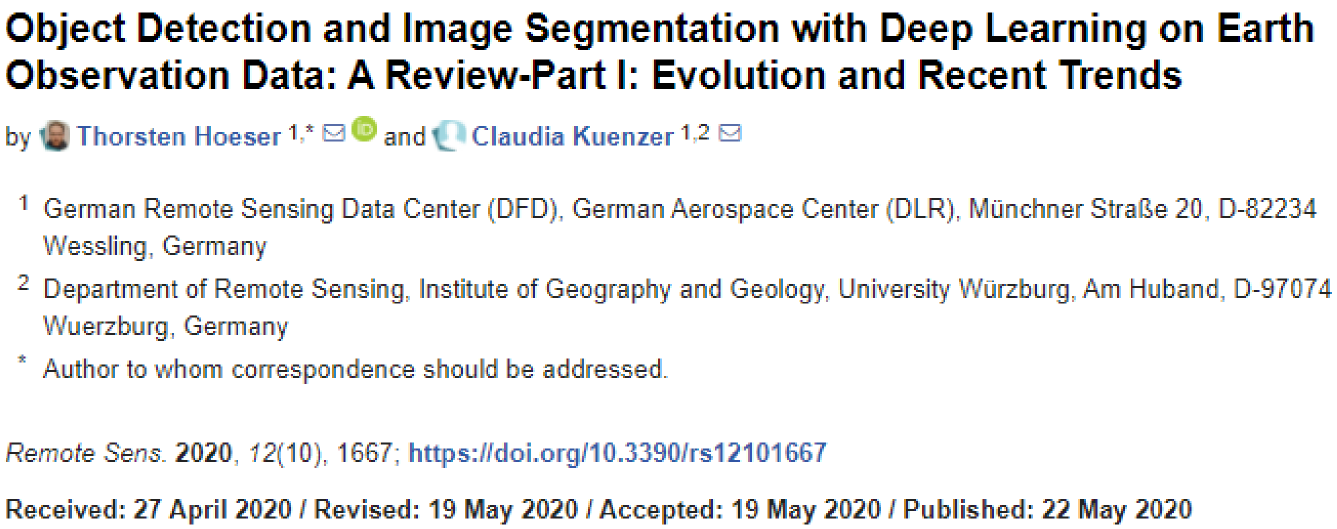
Getting Started with Keras

Overview

Keras is a high-level neural networks API developed with a focus on enabling fast experimentation. *Being able to go from idea to result with the least possible delay is key to doing good research.* Keras has the following key features:

- Allows the same code to run on CPU or on GPU, seamlessly.
- User-friendly API which makes it easy to quickly prototype deep learning models.
- Built-in support for convolutional networks (for computer vision), recurrent networks (for sequence processing), and any combination of both.
- Supports arbitrary network architectures: multi-input or multi-output models, layer sharing, model sharing, etc. This means that Keras is appropriate for building essentially any deep learning model, from a memory network to a neural Turing machine.

This website provides documentation for the R interface to Keras. See the main Keras website at https://keras.io for additional information on the project.


Object Detection and Image Segmentation with Deep Learning on Earth Observation Data: A Review-Part I: Evolution and Recent Trends

by Thorsten Hoeser [1,*] and Claudia Kuenzer [1,2]

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Hoeser & Kuenzer (2020) *Remote sensing*
https://www.mdpi.com/2072-4292/12/10/1667/htm

Summary

- Deep learning are state-of-the-art models for image segmentation. You should start to do DL now ☺
- Hope you learned something new today, thanks !

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