Convolutional Neural Networks in Matlab

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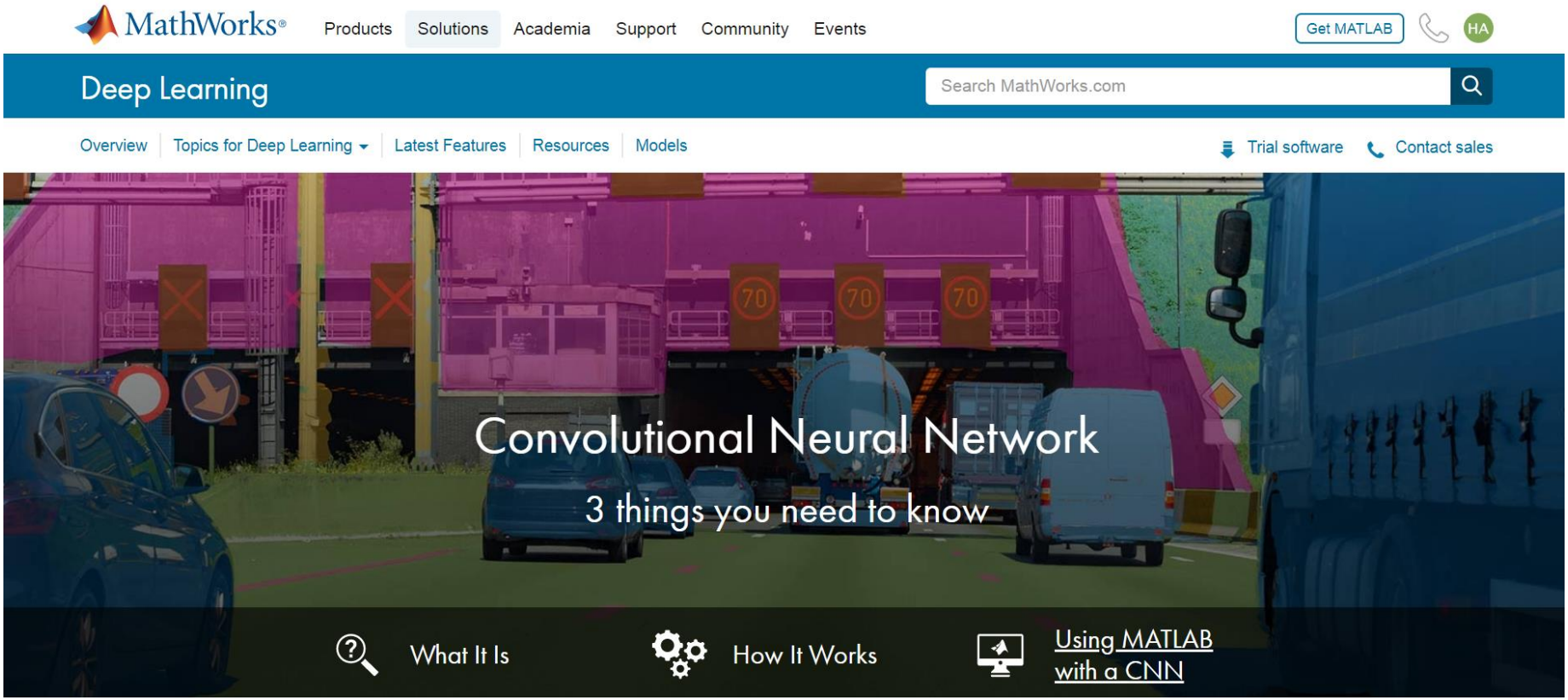
Convolutional Neural Networks

Cuerpo Académico de Investigación y Aplicaciones de la Inteligencia Artificial

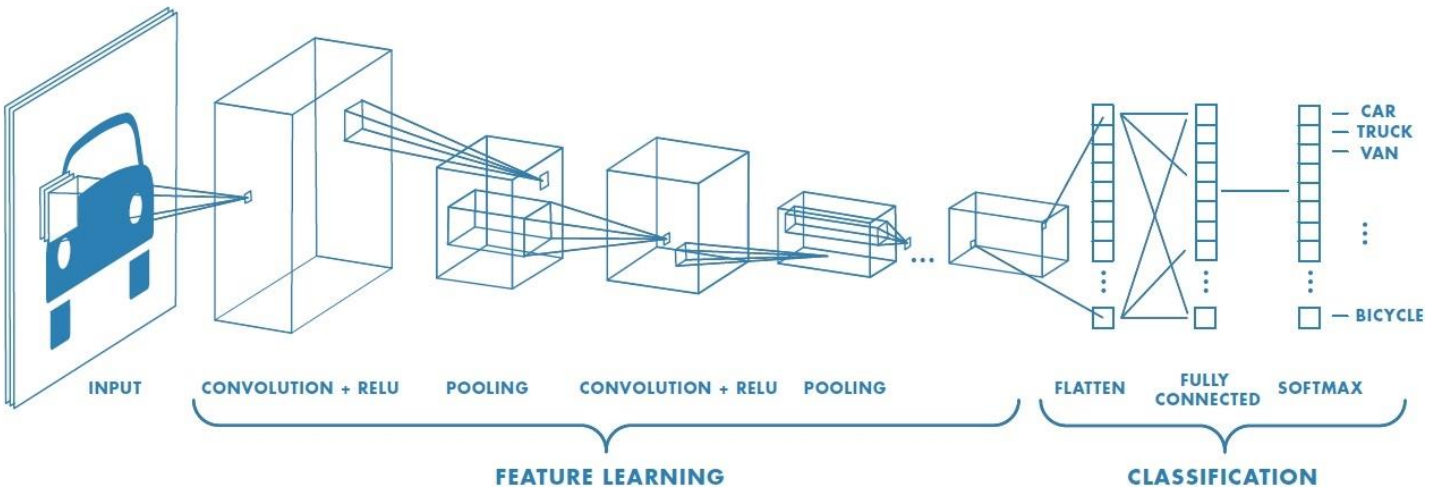
CNN in Matlab

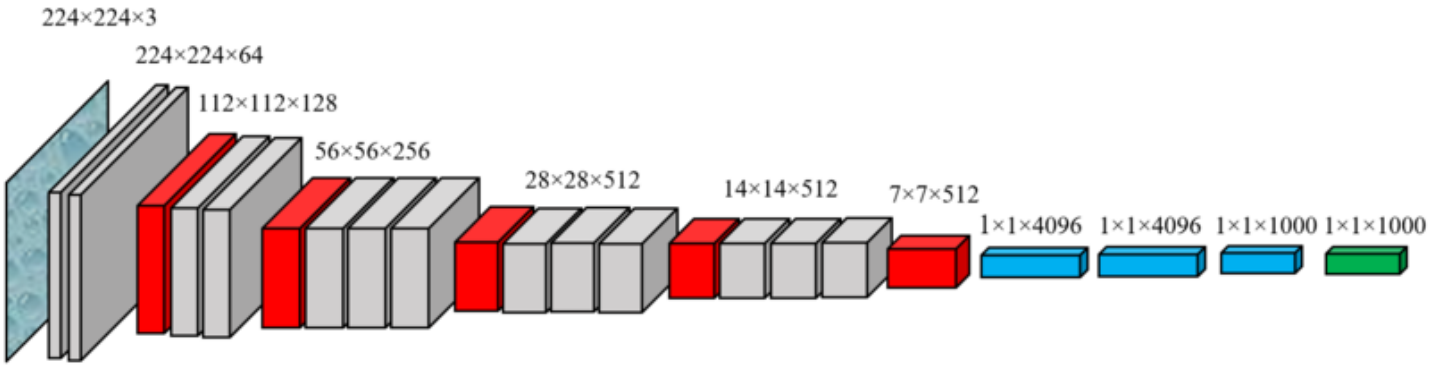


Material taken from MathWorks

https://www.mathworks.com/solutions/deep-learning/convolutional-neural-network.html

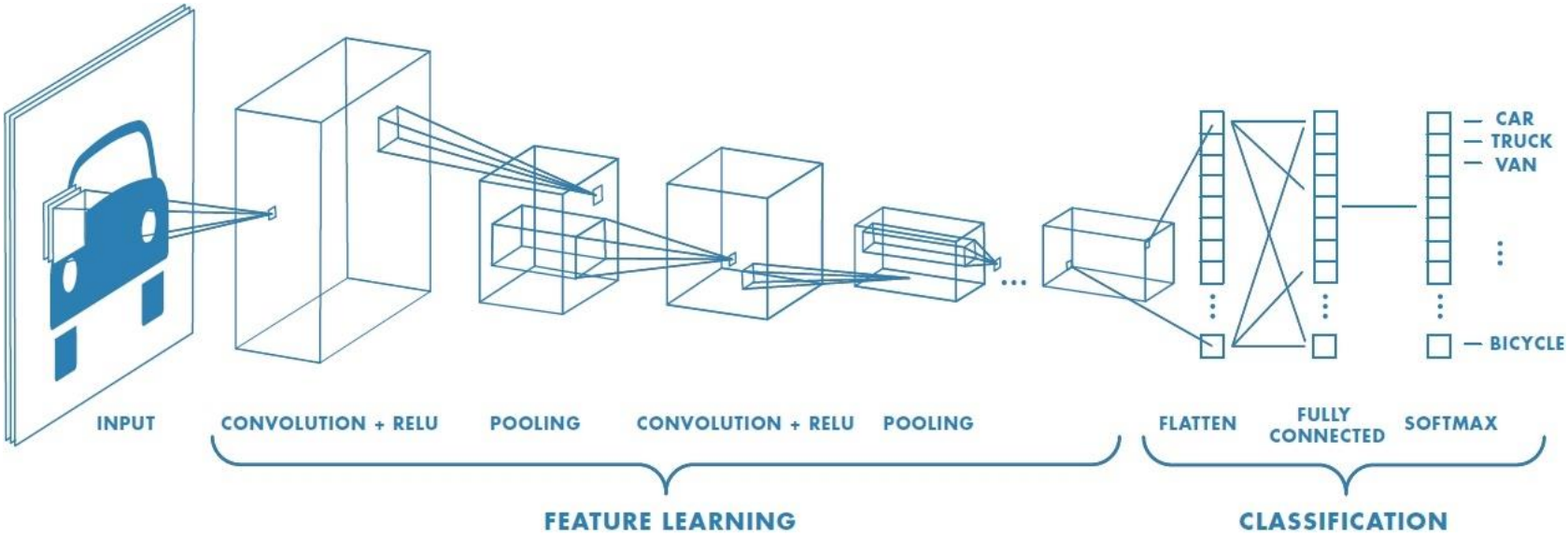
Convolutional Neural Networks





https://en.wikipedia.org/wiki/File:VGG_neural_network.png

Convolutional Neural Networks



MATLAB Commands

```
>> newnet = trainNetwork(data,layers,options)
```

MATLAB Variables

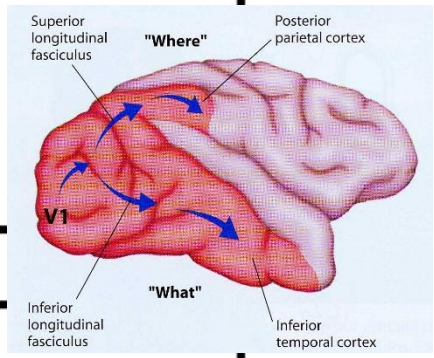
- layers
- data
- options

Convolutional Neural Networks

Classification

CNN - Deep Learning Toolbox™

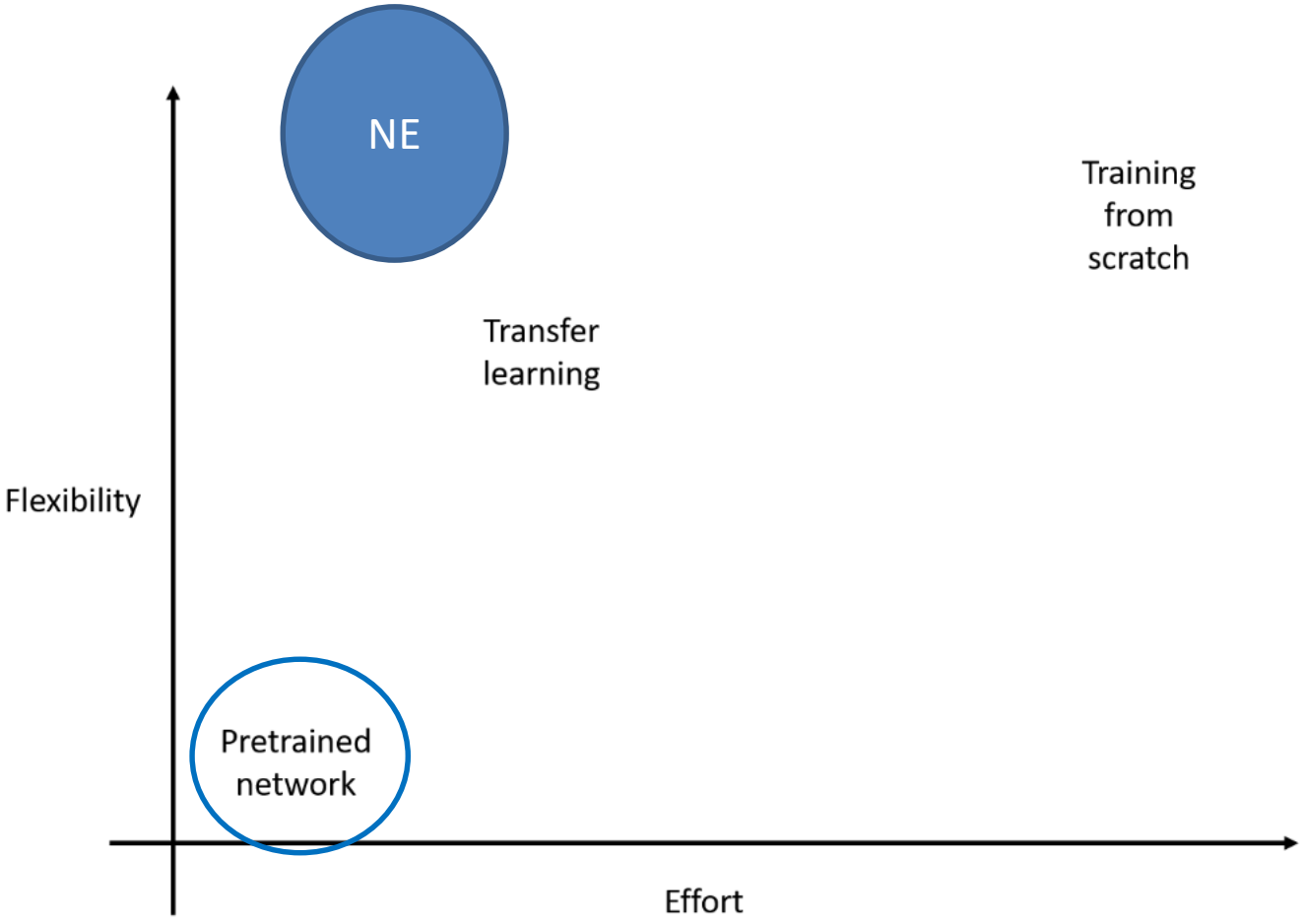
Regression



Object detection

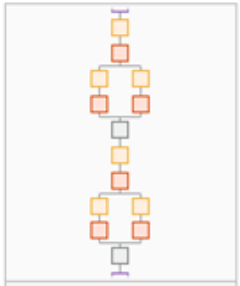
R-CNN - Computer Vision Toolbox™

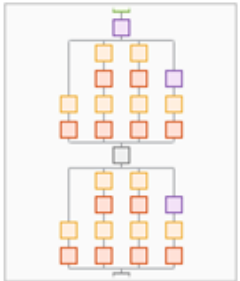
Convolutional Neural Networks

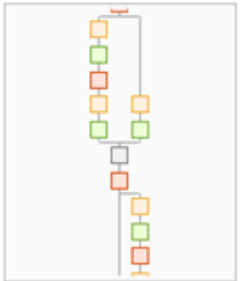


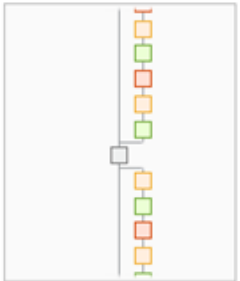
Networks

Pretrained Networks

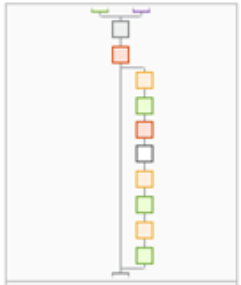

SqueezeNet

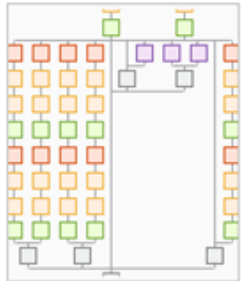

GoogLeNet

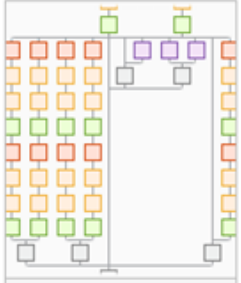

ResNet-50

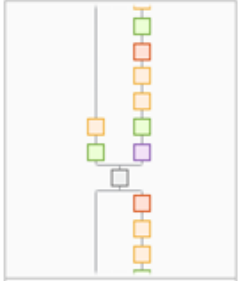

DarkNet-53

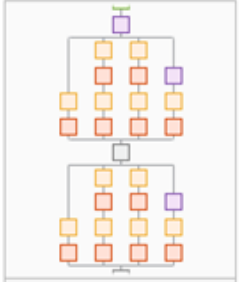

DarkNet-19

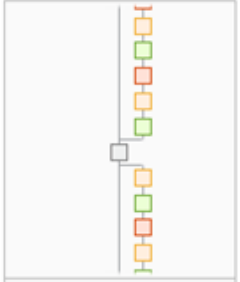

ShuffleNet

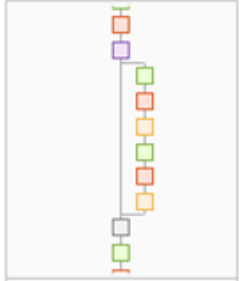

NasNet-Mobile

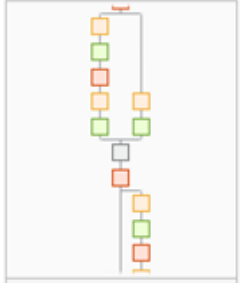

NasNet-Large

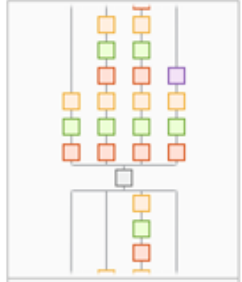

Xception

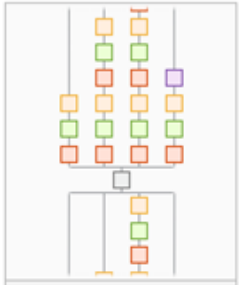

Places365-GoogLe...

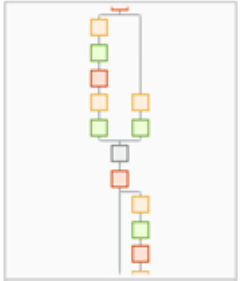

MobileNet-v2


DenseNet-201

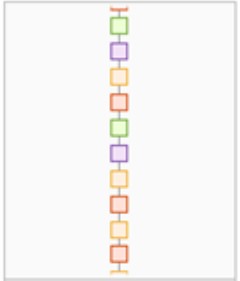

ResNet-18

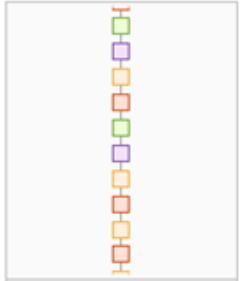

Inception-ResNet-v2


Inception-v3


ResNet-101

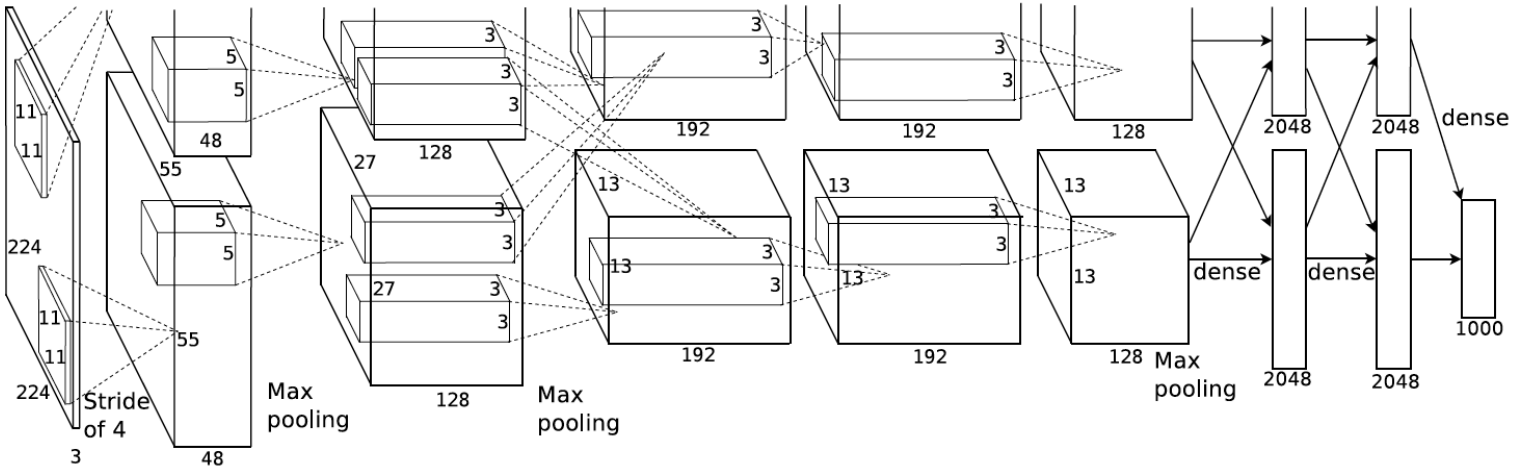

VGG-19


VGG-16


AlexNet

Alexnet

AlexNet is a pretrained Convolutional Neural Network (CNN) that has been trained on approximately 1.2 million images from the ImageNet Dataset (http://image-net.org/index). The model has 23 layers and can classify images into 1000 object categories (e.g. keyboard, mouse, coffee mug, pencil).



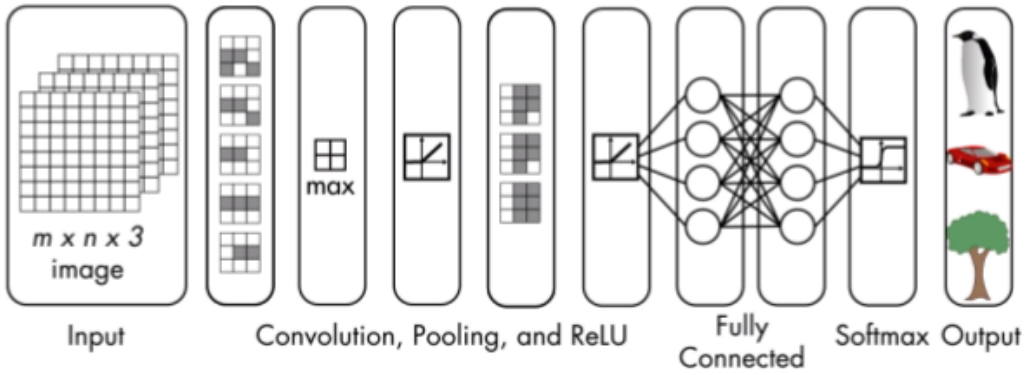
Alexnet in Matlab

Install: **Deep Learning Toolbox Model for AlexNet**
Network support package for the pretrained weights.

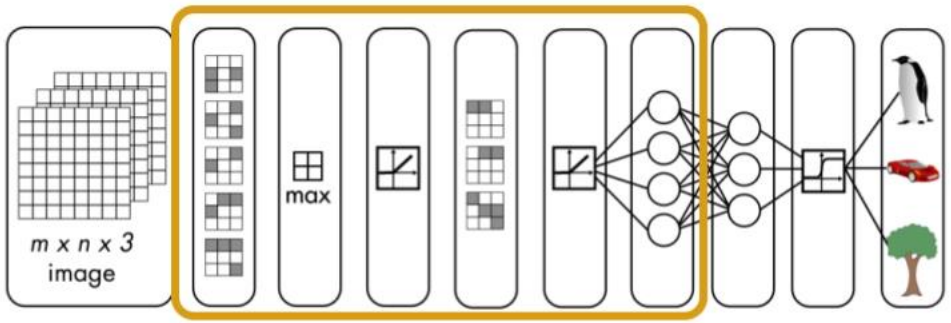
```
%Get AlexNet

net = alexnet;

layers = net.Layers;
```

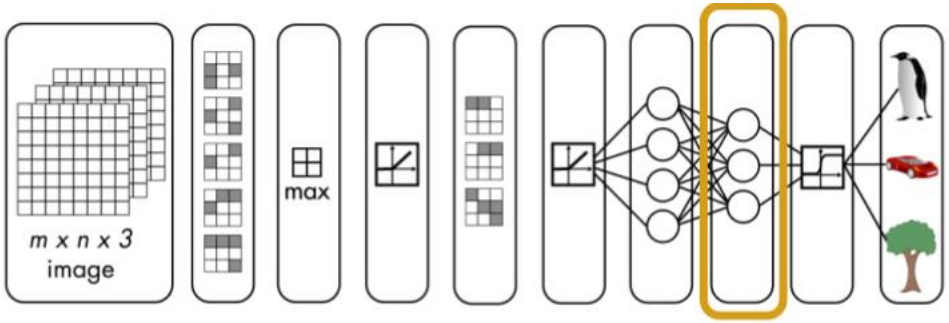


Structure



1	'data'	Image Input	227x227x3 images with 'zerocenter' normalization
2	'conv1'	Convolution	96 11x11x3 convolutions with stride [4 4] and padding [0 0 0 0]
3	'relu1'	ReLU	ReLU
4	'norm1'	Cross Channel Normalization	cross channel normalization with 5 channels per element
5	'pool1'	Max Pooling	3x3 max pooling with stride [2 2] and padding [0 0 0 0]
6	'conv2'	Convolution	256 5x5x48 convolutions with stride [1 1] and padding [2 2 2 2]
7	'relu2'	ReLU	ReLU
8	'norm2'	Cross Channel Normalization	cross channel normalization with 5 channels per element
9	'pool2'	Max Pooling	3x3 max pooling with stride [2 2] and padding [0 0 0 0]
10	'conv3'	Convolution	384 3x3x256 convolutions with stride [1 1] and padding [1 1 1 1]
11	'relu3'	ReLU	ReLU
12	'conv4'	Convolution	384 3x3x192 convolutions with stride [1 1] and padding [1 1 1 1]
13	'relu4'	ReLU	ReLU
14	'conv5'	Convolution	256 3x3x192 convolutions with stride [1 1] and padding [1 1 1 1]
15	'relu5'	ReLU	ReLU
16	'pool5'	Max Pooling	3x3 max pooling with stride [2 2] and padding [0 0 0 0]
17	'fc6'	Fully Connected	4096 fully connected layer
18	'relu6'	ReLU	ReLU
19	'drop6'	Dropout	50% dropout
20	'fc7'	Fully Connected	4096 fully connected layer
21	'relu7'	ReLU	ReLU
22	'drop7'	Dropout	50% dropout
23	'fc8'	Fully Connected	1000 fully connected layer
24	'prob'	Softmax	softmax
25	'output'	Classification Output	crossentropyex with 'tench', 'goldfish', and 998 other classes

Structure



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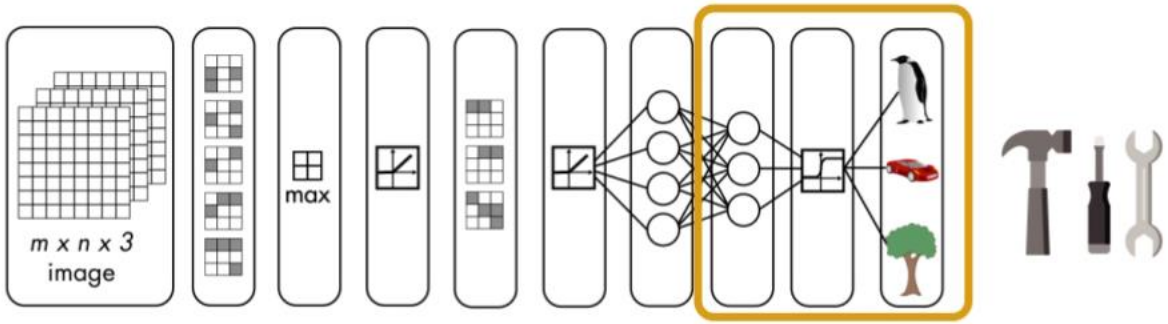

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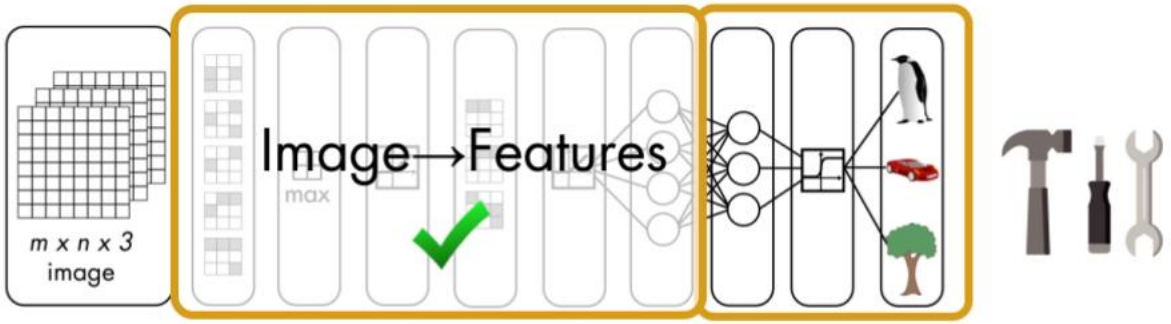

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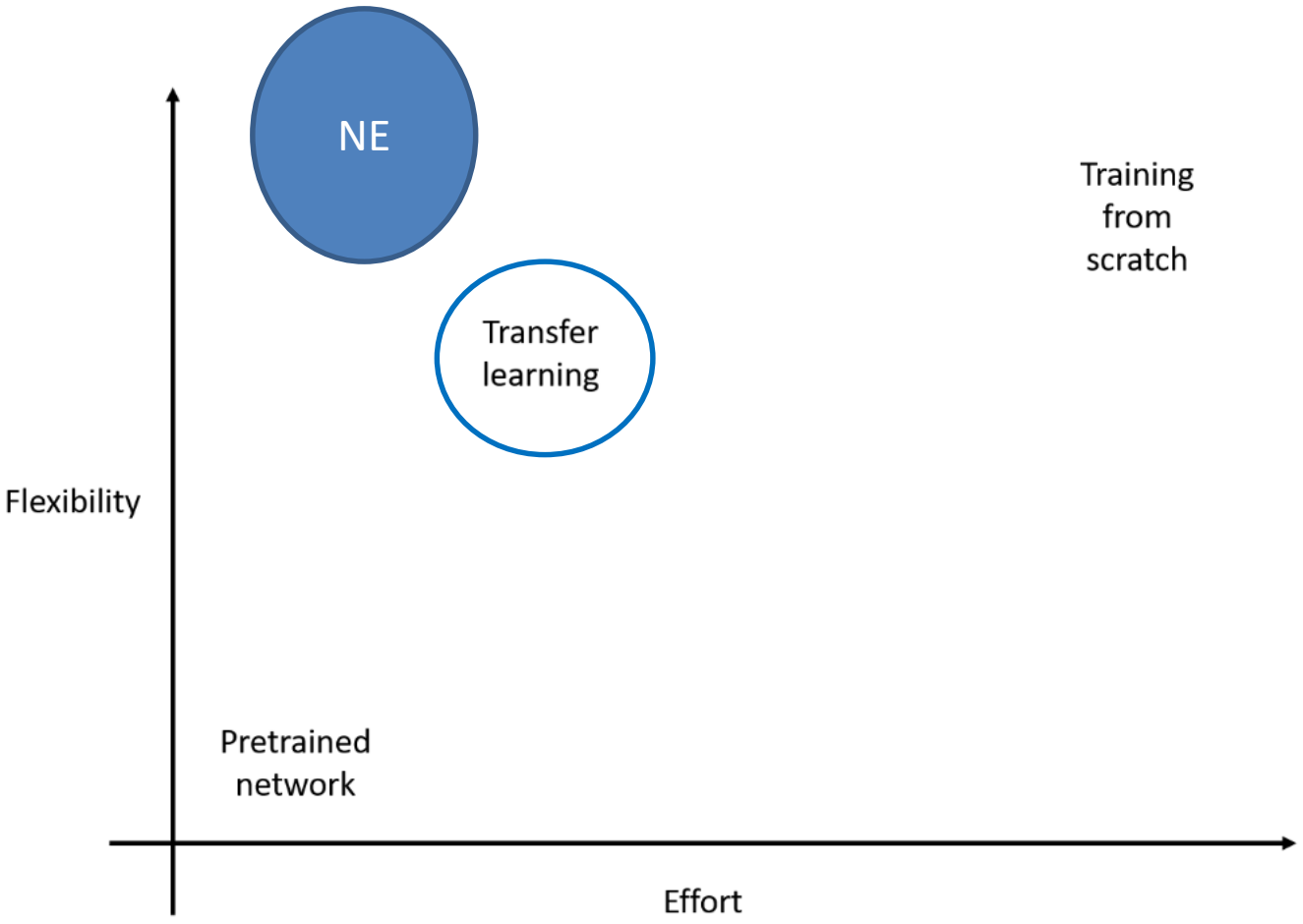
23	'fc8'	Fully Connected	1000 fully connected layer
24	'prob'	Softmax	softmax
25	'output'	Classification Output	crossentropyex with 'tench', 'goldfish', and 998 other classes

Pretrained Network

```
% CNN in 10 lines
camera=webcam;

nnet=alexnet;

while true
    picture=camera.snapshot;
    picture=imresize(picture,[227,227]);

    label=classify(nnet,picture);

    image(picture)
    title(char(label))
    drawnow;
end
```

Transfer learning



Transfer learning

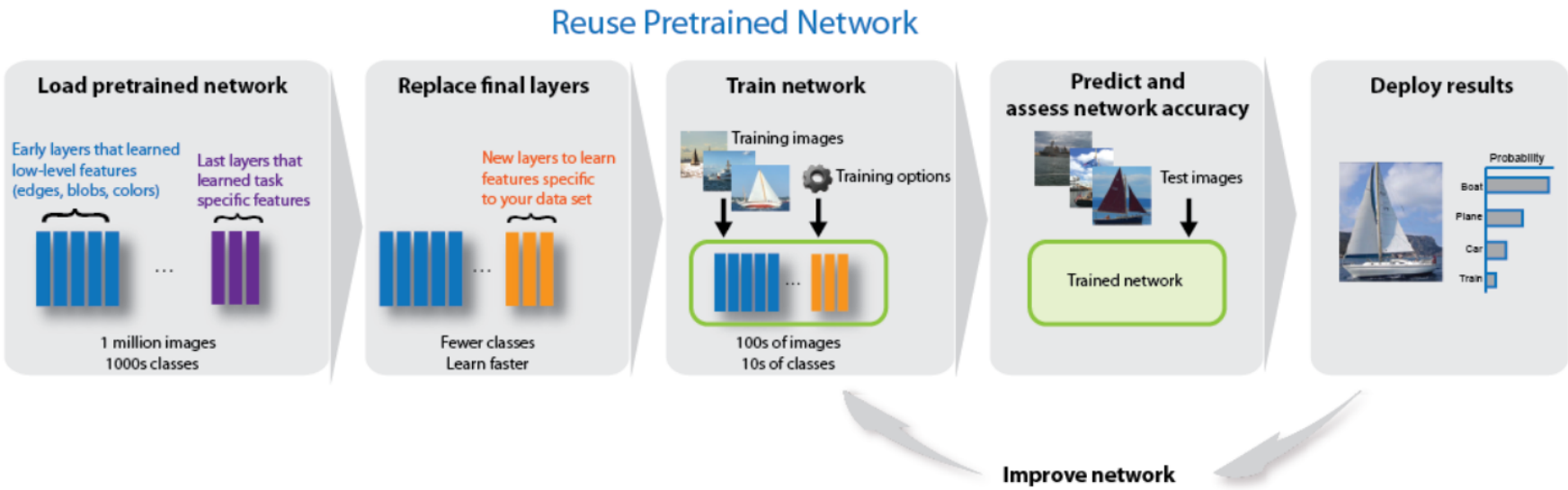
This example shows how to fine-tune a pretrained AlexNet convolutional neural network to perform classification on a new collection of images.

AlexNet has been trained on over a million images and can classify images into 1000 object categories (such as keyboard, coffee mug, pencil, and many animals). The network has learned rich feature representations for a wide range of images. The network takes an image as input and outputs a label for the object in the image together with the probabilities for each of the object categories.

Transfer learning is commonly used in deep learning applications. You can take a pretrained network and use it as a starting point to learn a new task. Fine-tuning a network with transfer learning is usually much faster and easier than training a network with randomly initialized weights from scratch. You can quickly transfer learned features to a new task using a smaller number of training images.

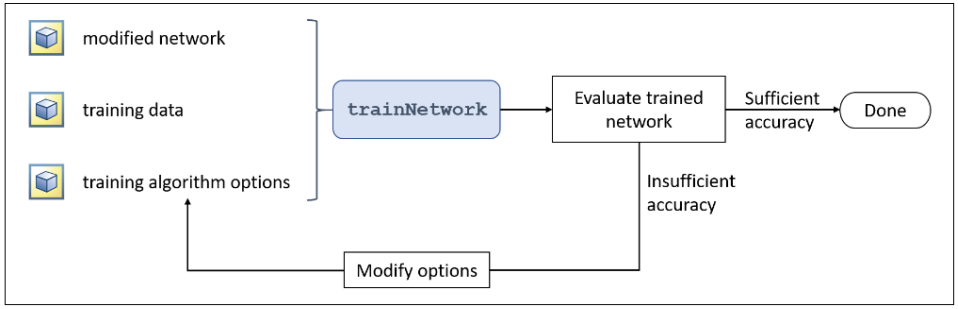
This example uses:
Deep Learning Toolbox
Deep Learning Toolbox Model for AlexNet Network

View MATLAB Command



Transfer learning

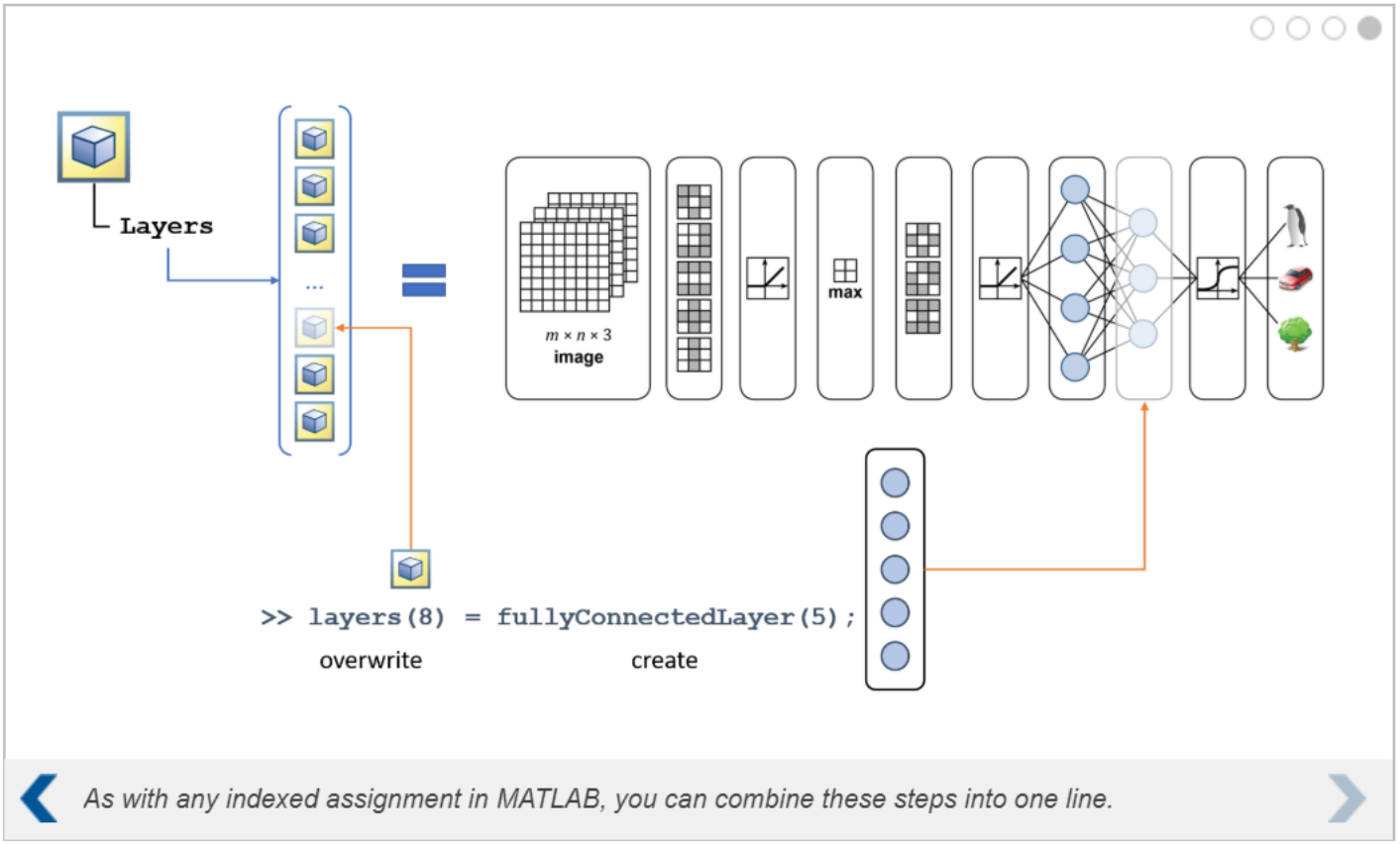
Typical workflow for transfer learning



To perform transfer learning, you need to create three components:

1. An array of layers representing the network architecture. For transfer learning, this is created by modifying a preexisting network such as AlexNet.
2. Images with known labels to be used as training data. This is typically provided as a datastore.

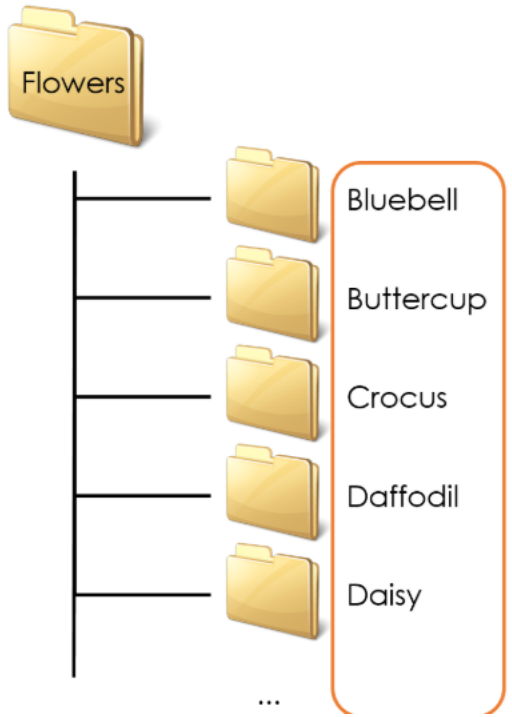
Transfer learning



Data

Labeling training images

When training a network, you need to provide known labels for the training images. The `Flowers` folder contains 12 subfolders, each of which contains 80 images of one type of flower. The name of the folder can therefore be used to provide the labels needed for training.

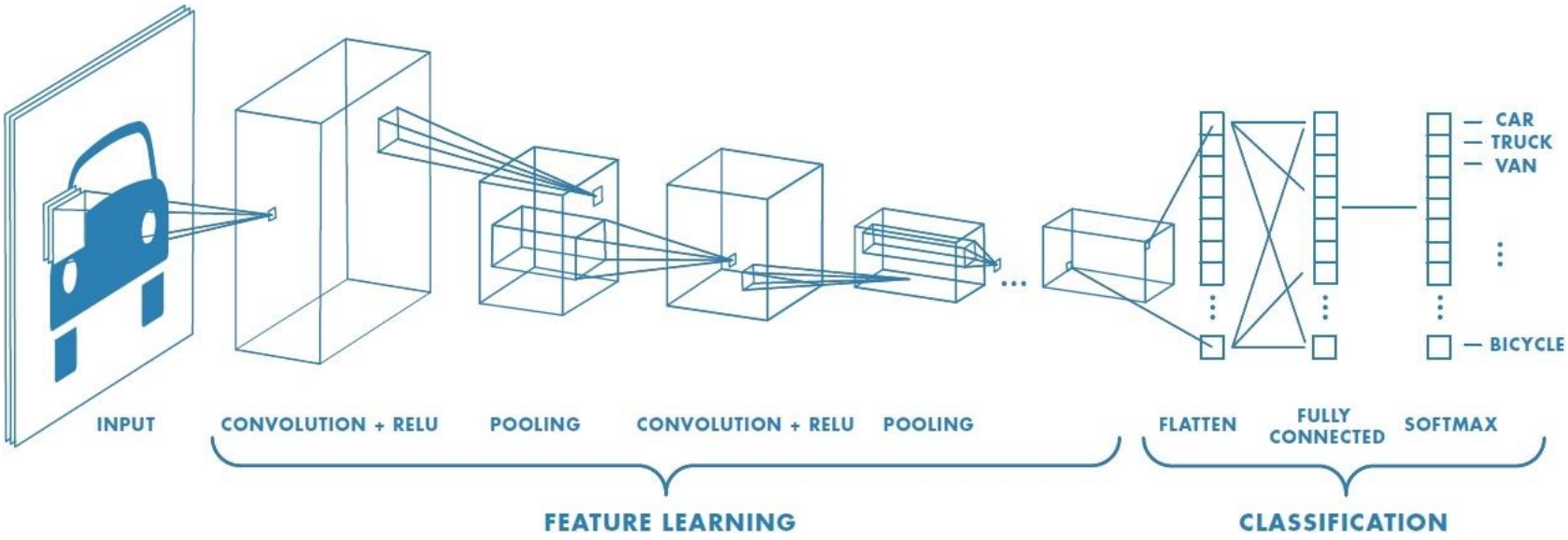


GPU device check

```
% Get GPU device information
deviceInfo = gpuDevice
% Check the GPU compute capability
computeCapability = str2double(deviceInfo.ComputeCapability);
```

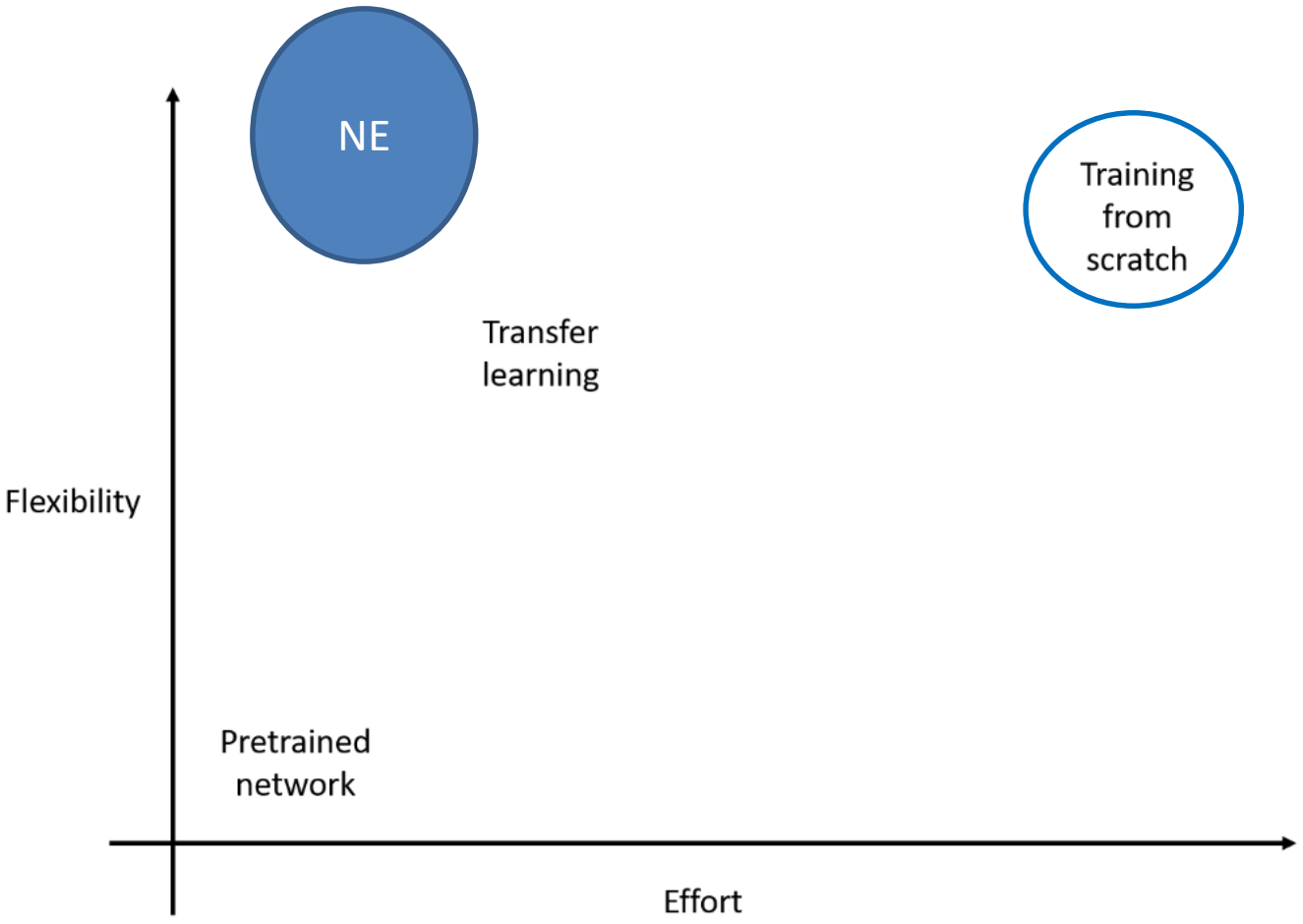
```
CUDADevice with properties:

                      Name: 'Quadro P1000'
                     Index: 1
         ComputeCapability: '6.1'
           SupportsDouble: 1
            DriverVersion: 11.2000
           ToolkitVersion: 11.2000
       MaxThreadsPerBlock: 1024
        MaxShmemPerBlock: 49152 (49.15 KB)
       MaxThreadBlockSize: [1024 1024 64]
              MaxGridSize: [2.1475e+09 65535 65535]
               SIMDWidth: 32
             TotalMemory: 4294967296 (4.29 GB)
         AvailableMemory: 3432408679 (3.43 GB)
     MultiprocessorCount: 5
            ClockRateKHz: 1480500
             ComputeMode: 'Default'
    GPUOverlapsTransfers: 1
  KernelExecutionTimeout: 1
        CanMapHostMemory: 1
         DeviceSupported: 1
         DeviceAvailable: 1
          DeviceSelected: 1
```

Transfer learning



See code: TransfL_Alexnet1.m (Flowers)

Training from scratch

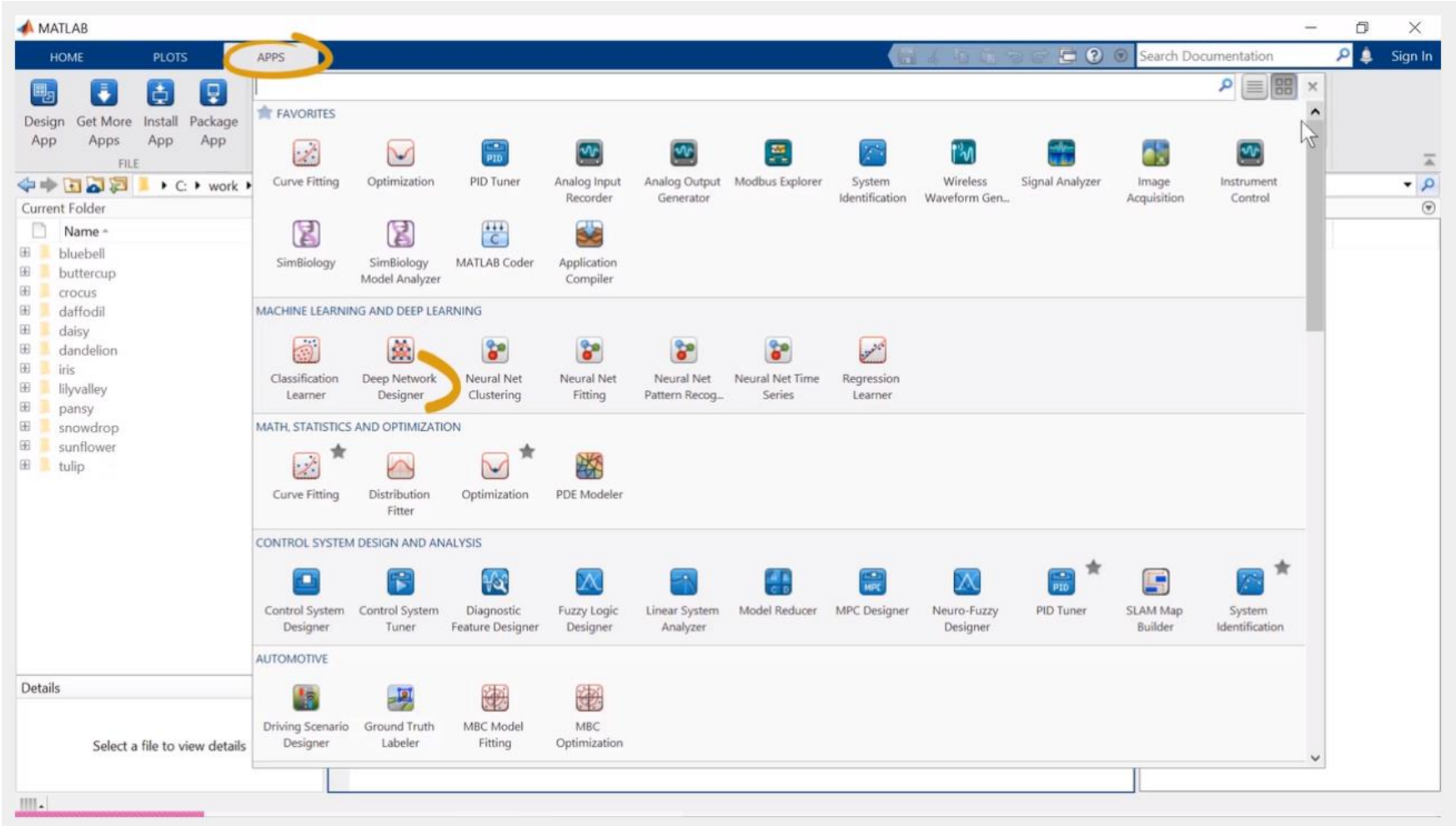


Training from scratch (Layers)

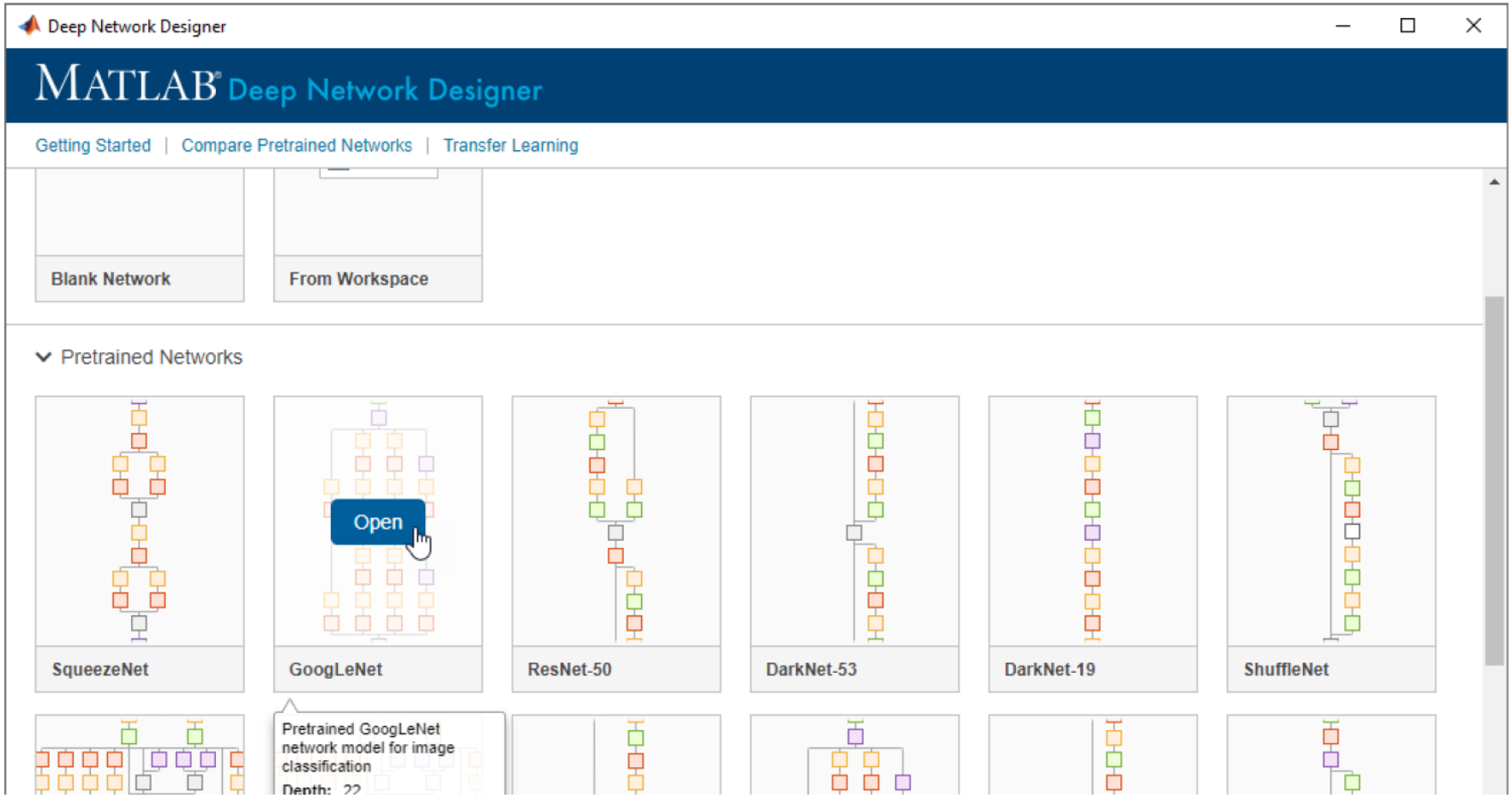
Example 1: Scratch_Digits.m

analyzeNetwork(net)

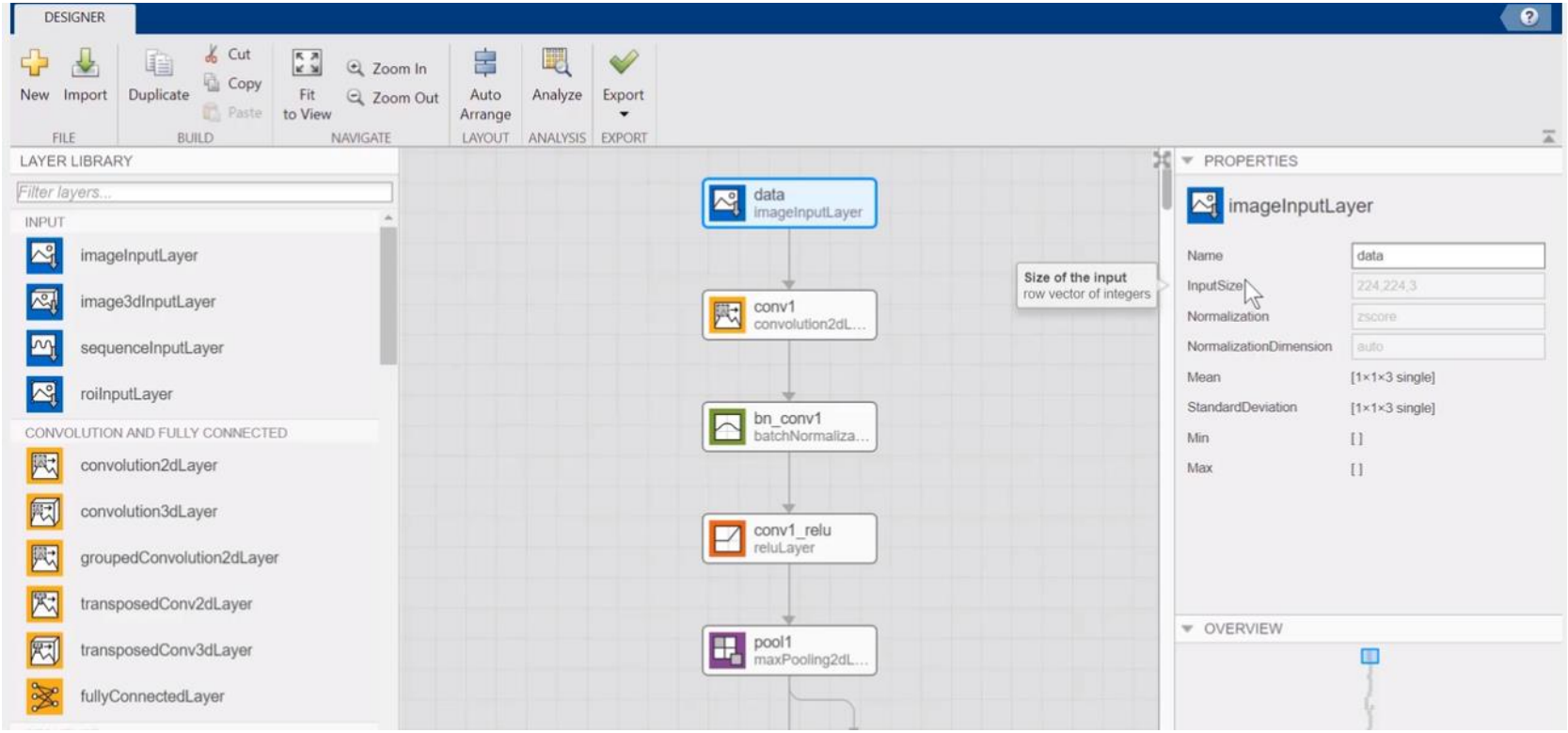
Deep Network Designer



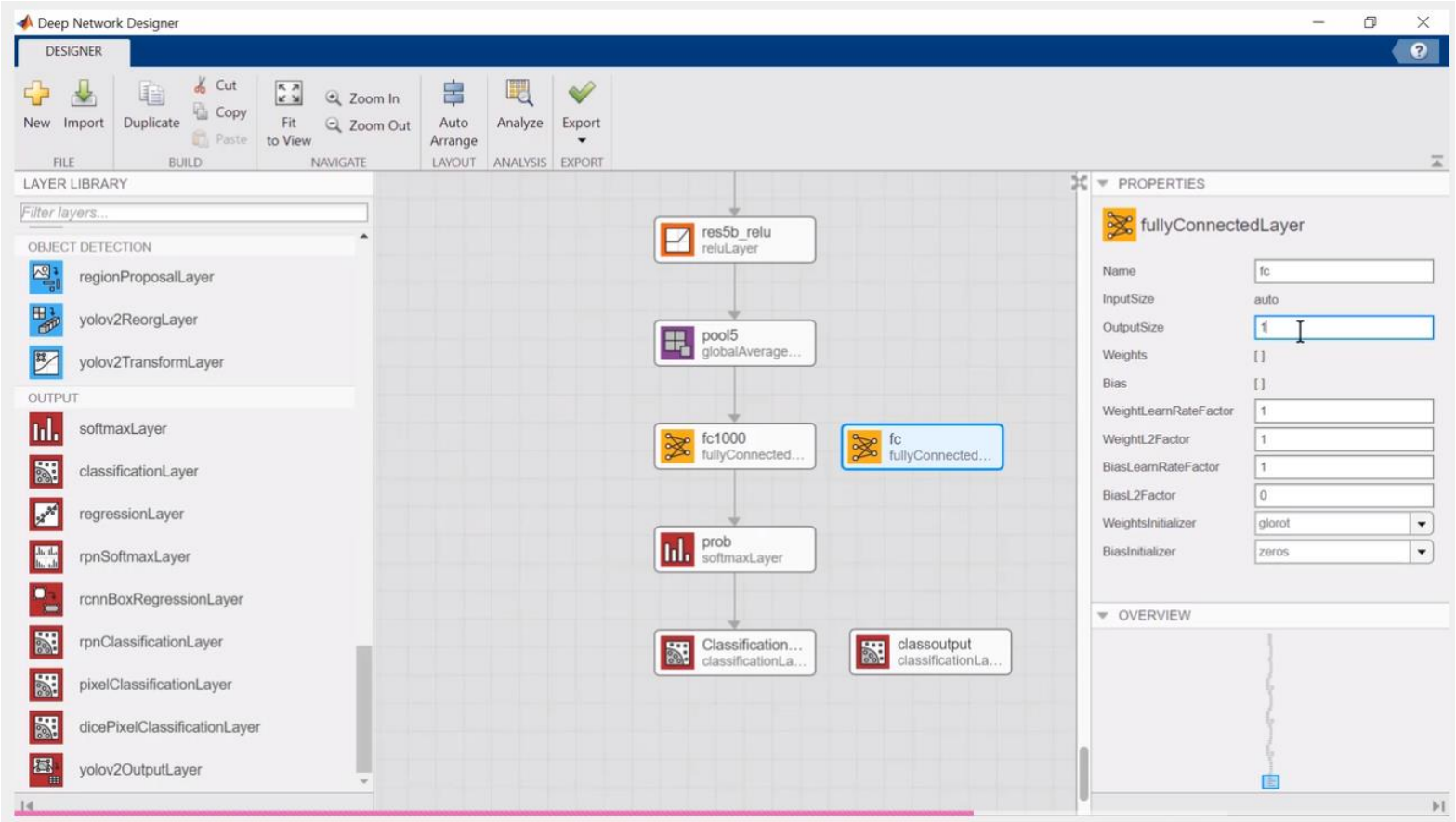
Deep Network Designer



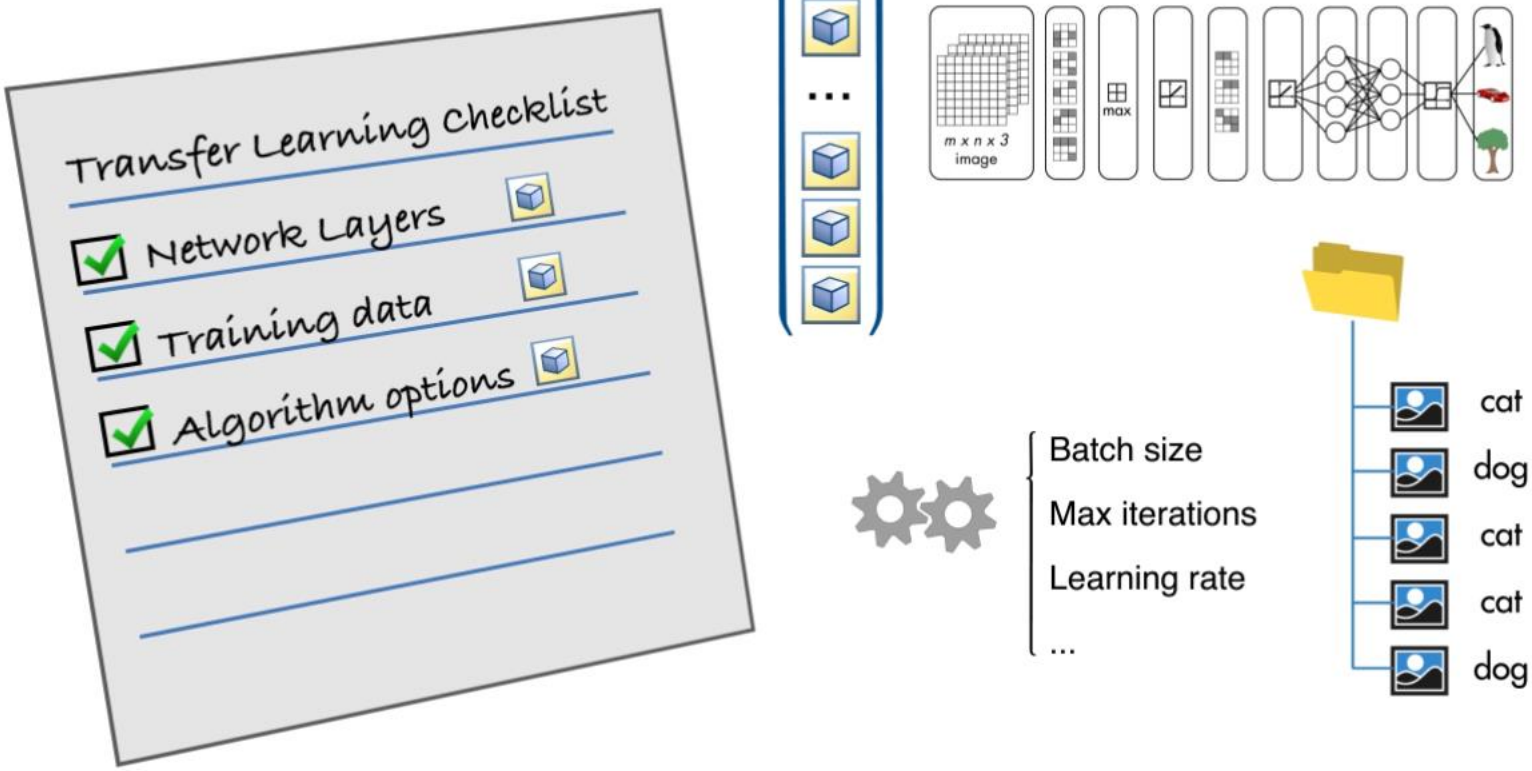
Deep Network Designer



Deep Network Designer

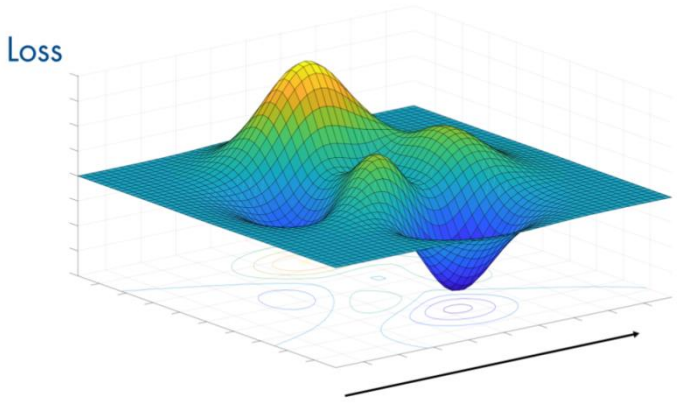


Training


Transfer Learning Checklist
Network Layers
Training data
Algorithm options
...
m x n x 3
image
max
Batch size
Max iterations
Learning rate
...
cat
dog
cat
cat
dog

Optimization parameters

See options code.



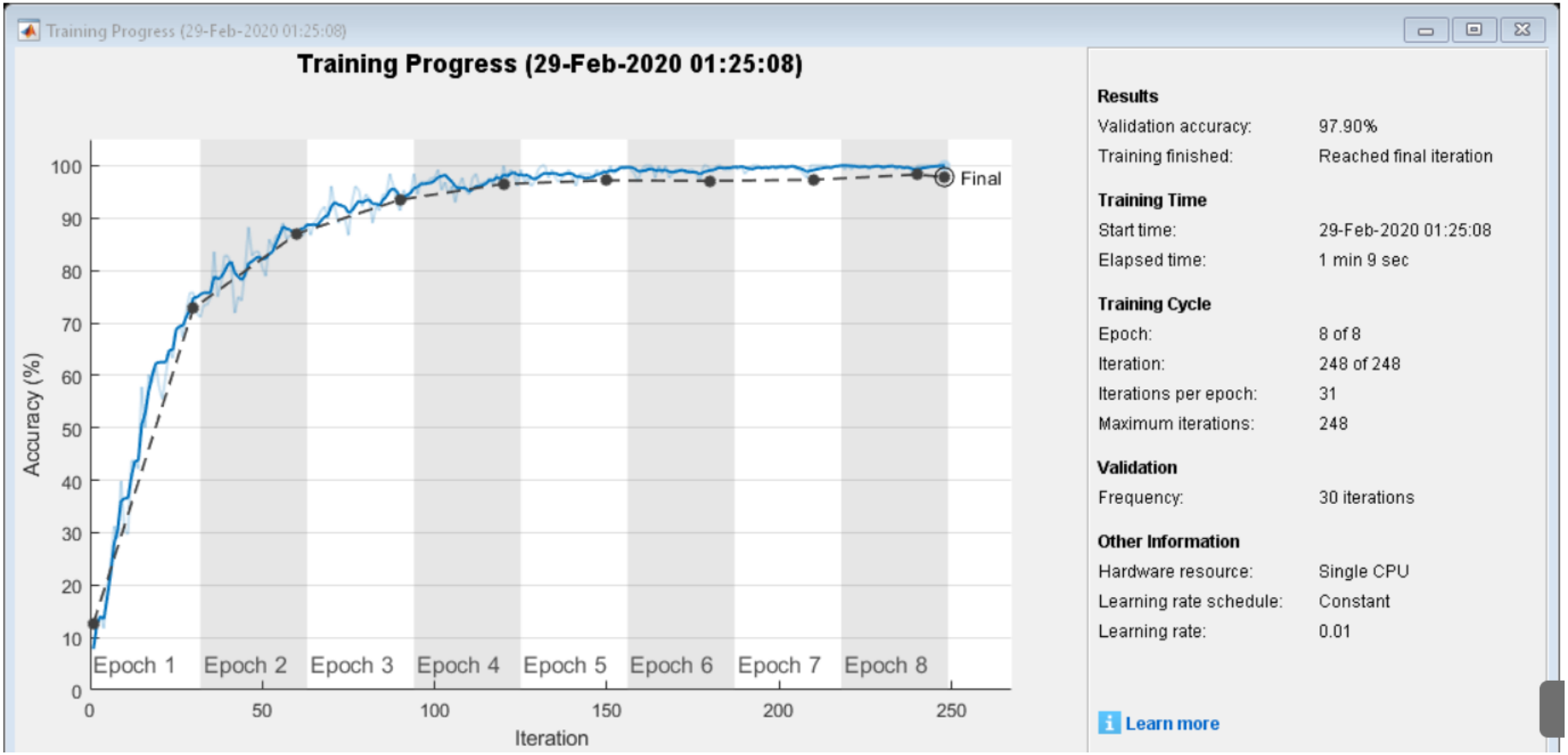
Training

```
>> newnet = trainNetwork(data,layers,options)
```

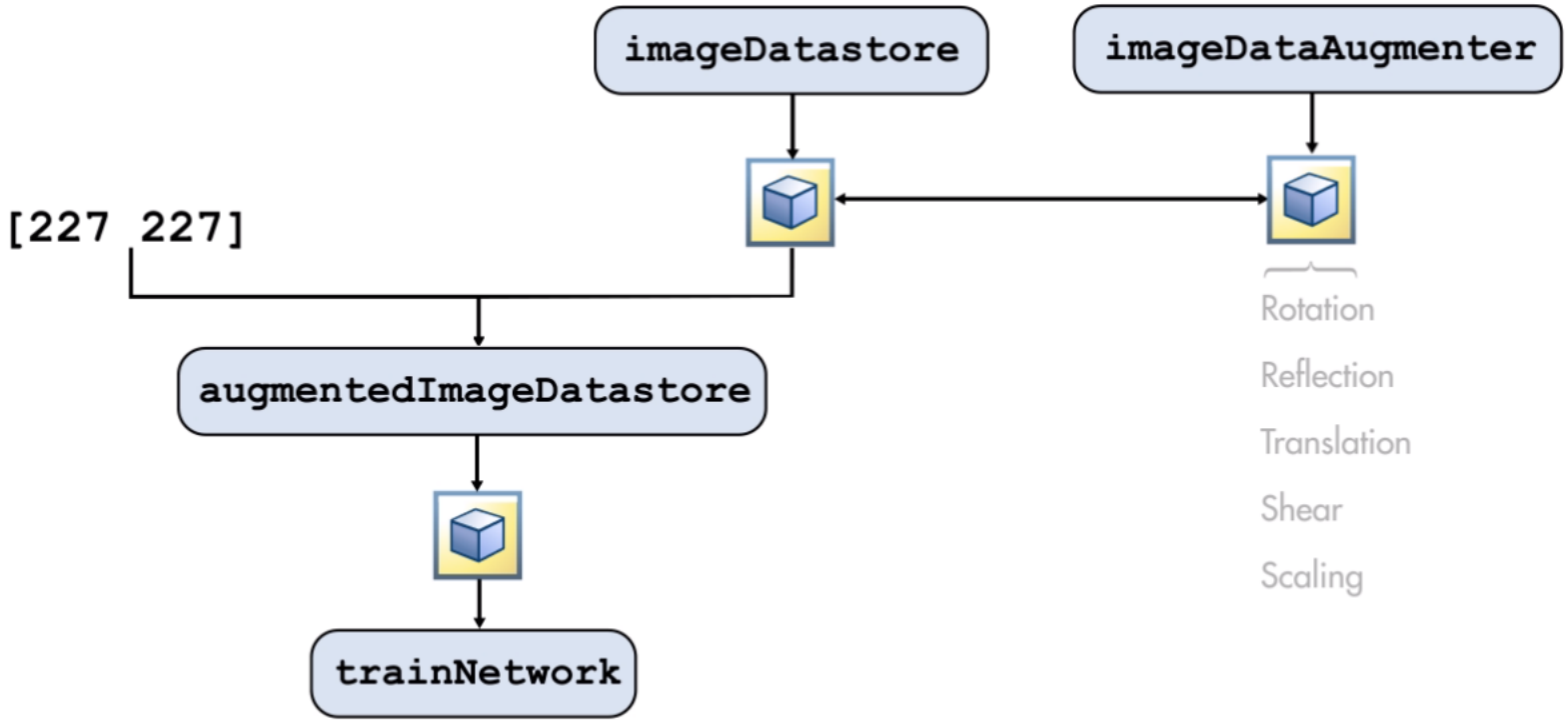
```
Training on single GPU.
Initializing image normalization.
```

Epoch	Iteration	Time Elapsed (seconds)	Mini-batch Loss	Mini-batch Accuracy	Base Learning Rate
1	1	0.47	3.5061	7.81%	0.0010
3	10	10.31	0.7686	75.00%	0.0010
5	20	18.96	0.2371	92.19%	0.0010
8	30	27.43	0.0770	97.66%	0.0010
10	40	35.31	0.0336	99.22%	0.0010
13	50	43.17	0.0289	99.22%	0.0010
15	60	50.15	0.0104	100.00%	0.0010
18	70	56.84	0.0072	100.00%	0.0010
20	80	63.00	0.0210	99.22%	0.0010
23	90	69.37	0.0035	100.00%	0.0010

Training


Training Progress (29-Feb-2020 01:25:08)
Training Progress (29-Feb-2020 01:25:08)
Accuracy (%)
Iteration
Final
Epoch 1
Epoch 2
Epoch 3
Epoch 4
Epoch 5
Epoch 6
Epoch 7
Epoch 8
Results
Validation accuracy: 97.90%
Training finished: Reached final iteration
Training Time
Start time: 29-Feb-2020 01:25:08
Elapsed time: 1 min 9 sec
Training Cycle
Epoch: 8 of 8
Iteration: 248 of 248
Iterations per epoch: 31
Maximum iterations: 248
Validation
Frequency: 30 iterations
Other Information
Hardware resource: Single CPU
Learning rate schedule: Constant
Learning rate: 0.01
Learn more

Data


imageDatastore
imageDataAugmenter
[227 227]
Rotation
Reflection
Translation
Shear
Scaling
augmentedImageDatastore
trainNetwork

Data augmentation in Matlab

imageDataAugmenter

Description

An image data augmenter configures a set of preprocessing options for image augmentation, such as resizing, rotation, and reflection. The imageDataAugmenter is used by an augmentedImageDatastore to generate batches of augmented images. For more information, see Augment Images for Training.

Syntax

```
aug = imageDataAugmenter
aug = imageDataAugmenter(Name,Value)
```

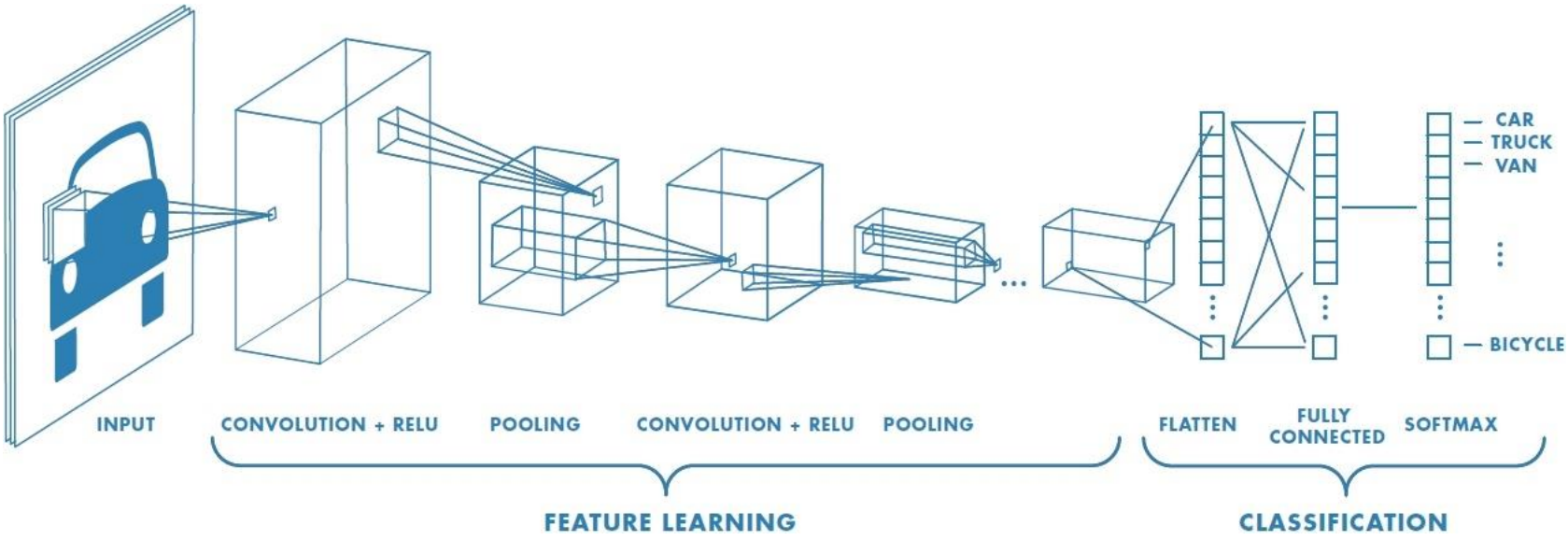
Data augmentation

```
% Create an imageDataAugmenter object that specifies
preprocessing options for image augmentation

[XTrain,YTrain] = digitTrain4DArrayData;

imageAugmenter = imageDataAugmenter( ...
    'RandRotation',[-20,20], ...
    'RandXTranslation',[-3 3], ...
    'RandYTranslation',[-3 3])

imageSize = [28 28 1];

augimds =
augmentedImageDatastore(imageSize,XTrain,YTrain,'DataAug
mentation',imageAugmenter);
```

Training from scratch (Layers)

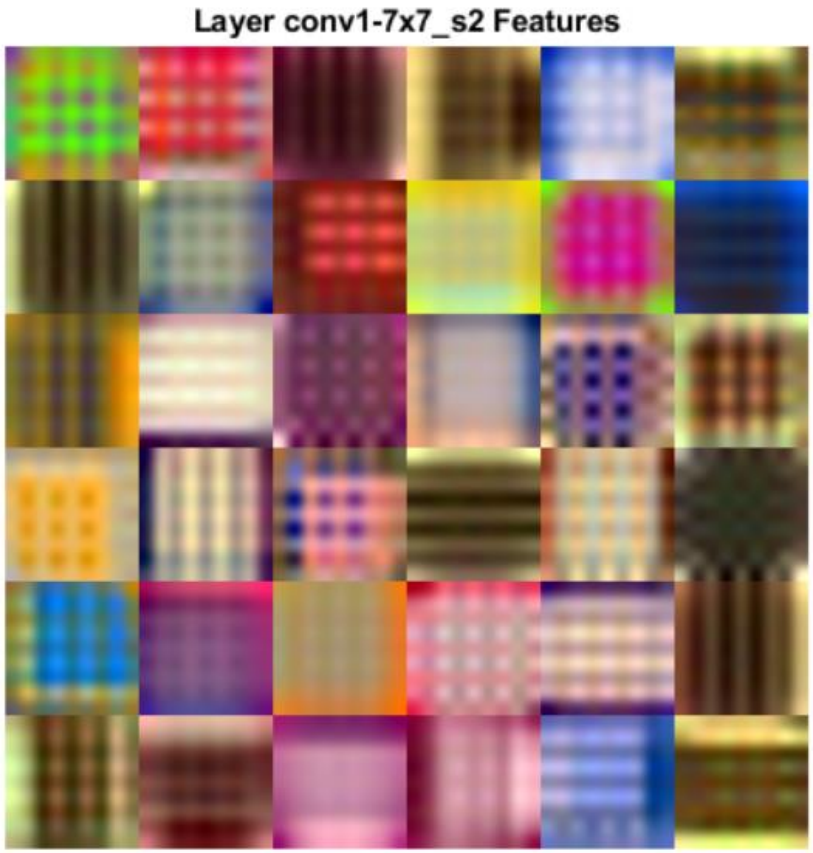
Example 2: Scratch_Digits_Augment.m

Feature extraction



See: Demo_FeatureExtraction.m (cfar10)

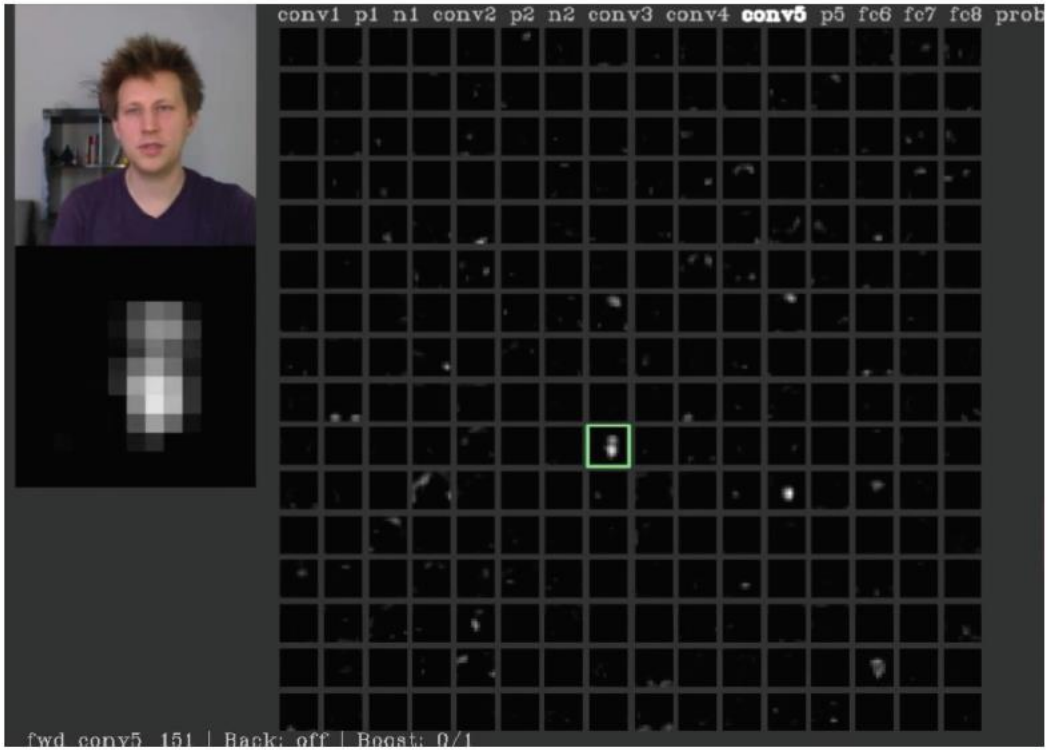
Visualize Features of a CNN



https://www.mathworks.com/help/deeplearning/ug/visualize-features-of-a-convolutional-neural-network.html

Visualize Features of a CNN

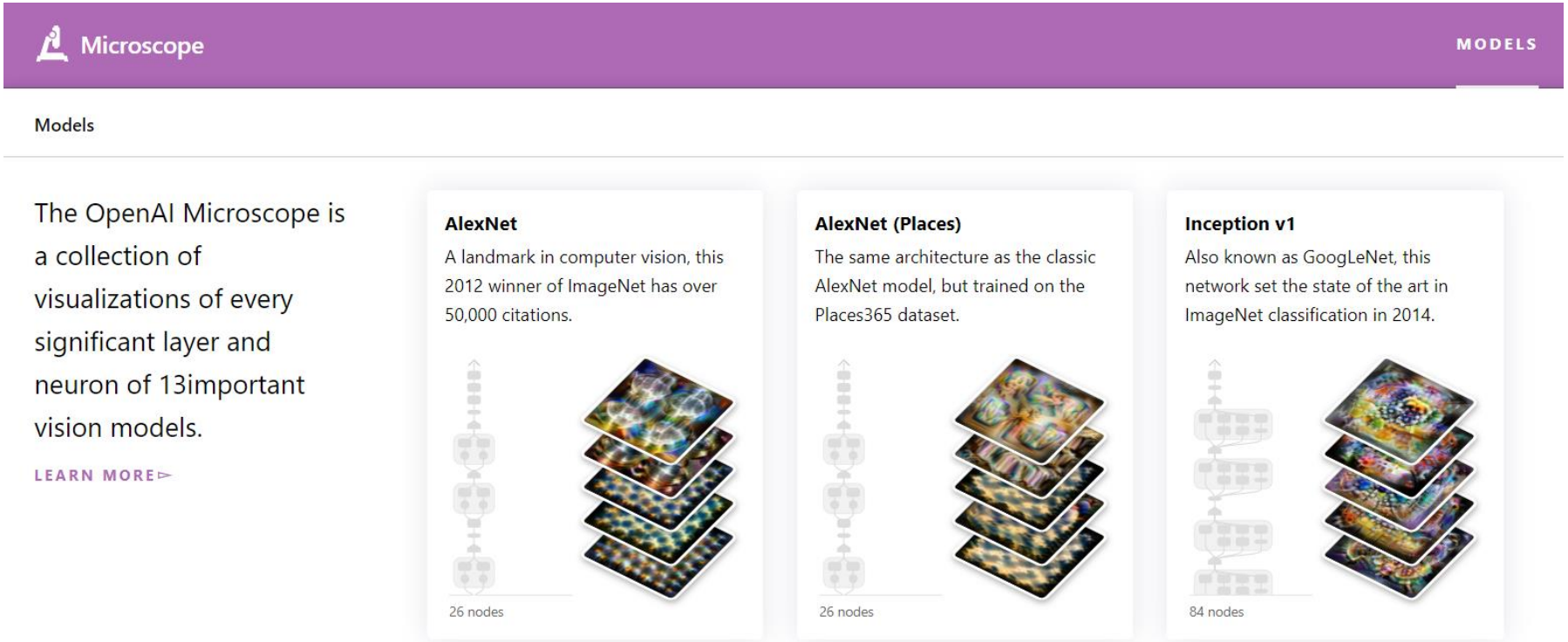
conv5 feature map is 128x13x13; visualize as 128 13x13 grayscale images



Yosinski et al, "Understanding Neural Networks Through Deep Visualization", ICML DL Workshop 2014.
Figure copyright Jason Yosinski, 2014. Reproduced with permission.

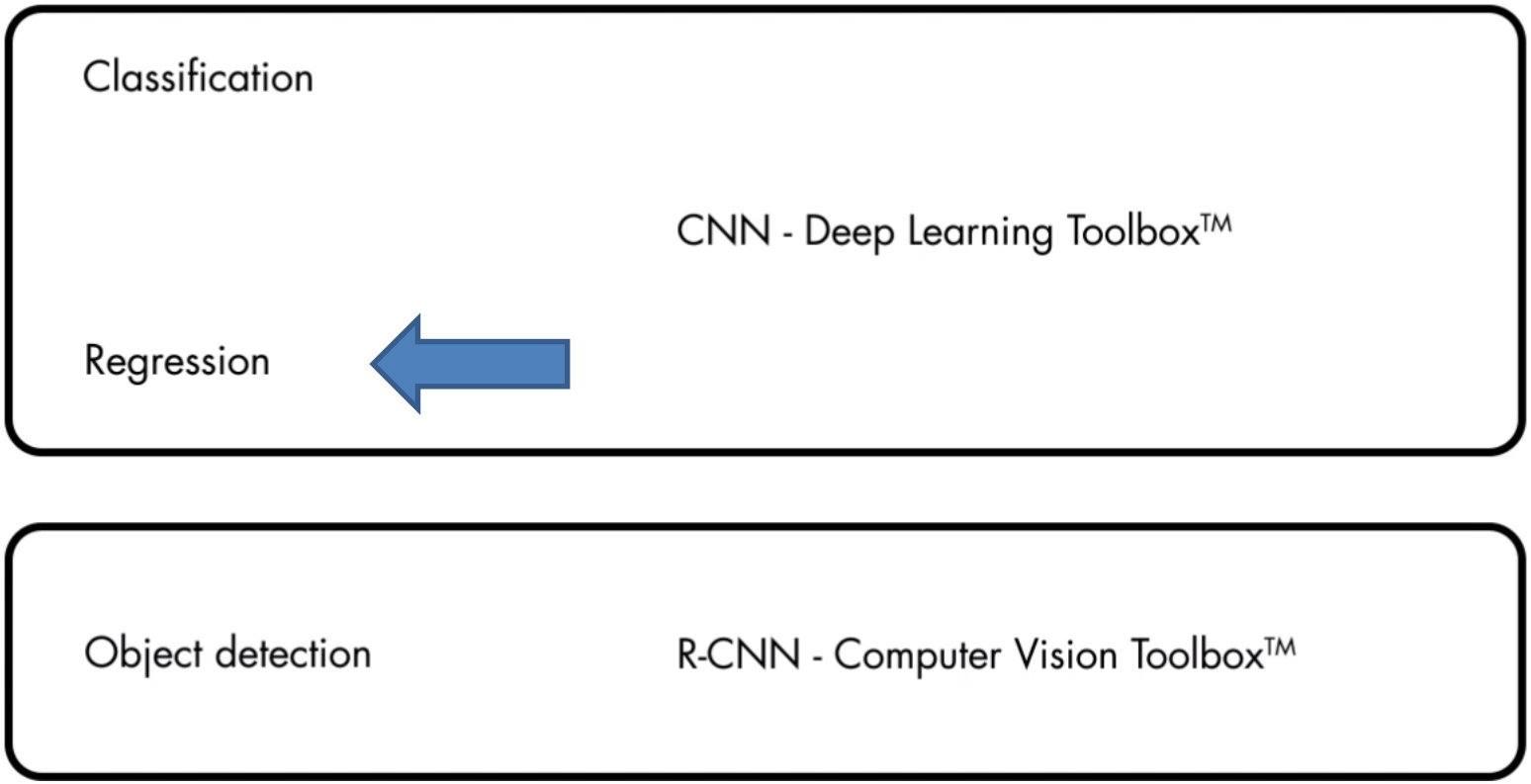
https://www.youtube.com/watch?v=AgkfIQ4IGaM

Understanding CNN

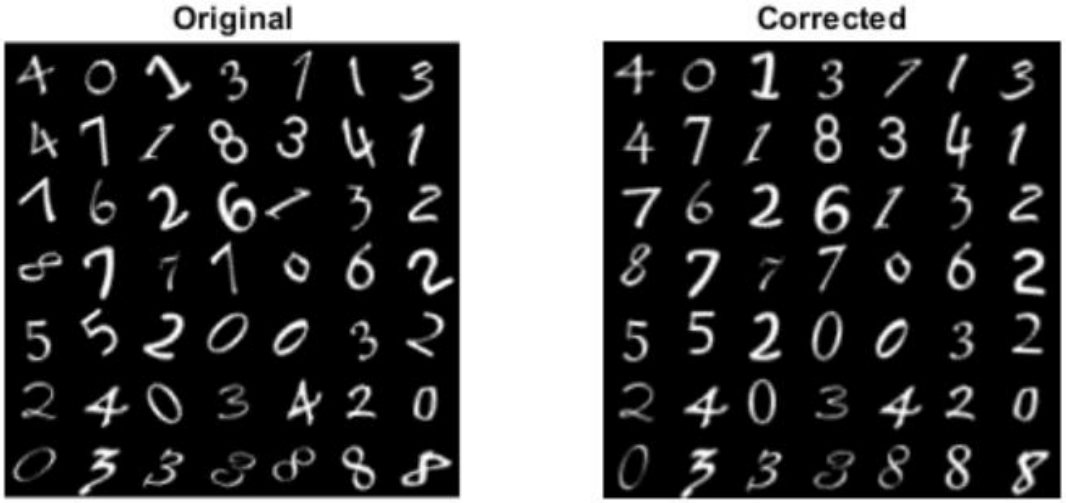


https://microscope.openai.com/models

Convolutional Neural Networks



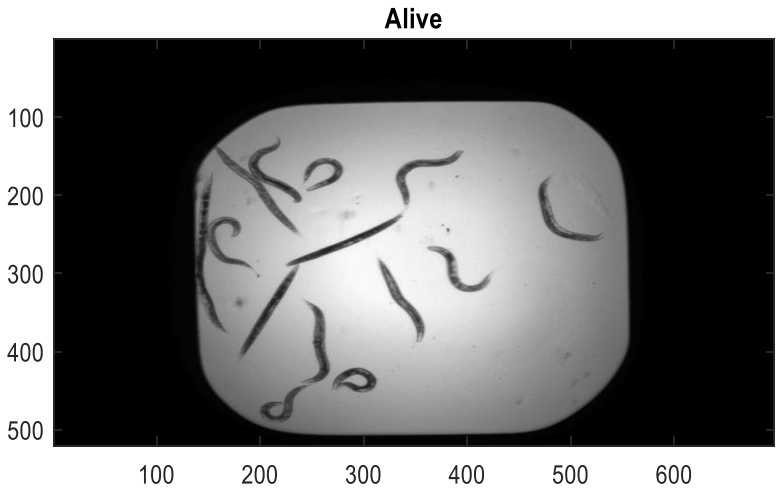
CNN for regression

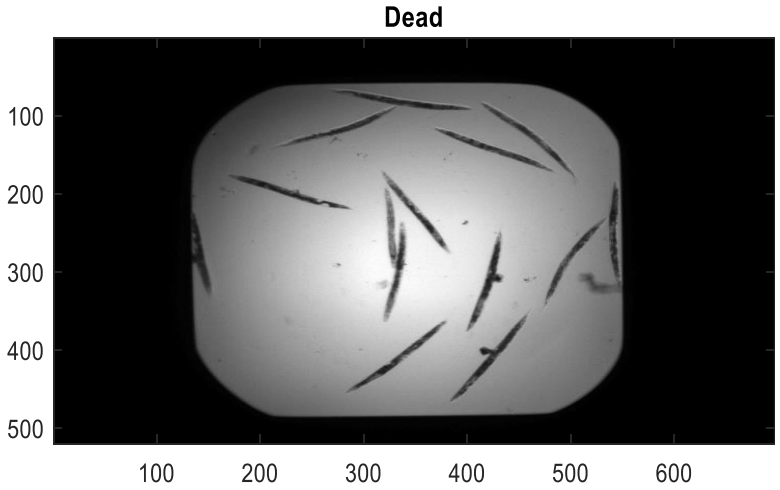


See: Scratch_Digits_Regress.m

Homework 12: Worm classification

- Propose and implement a methodology using CNN to perform a binary classification of the worm database.
- A minimum accuracy of 90% is expected.



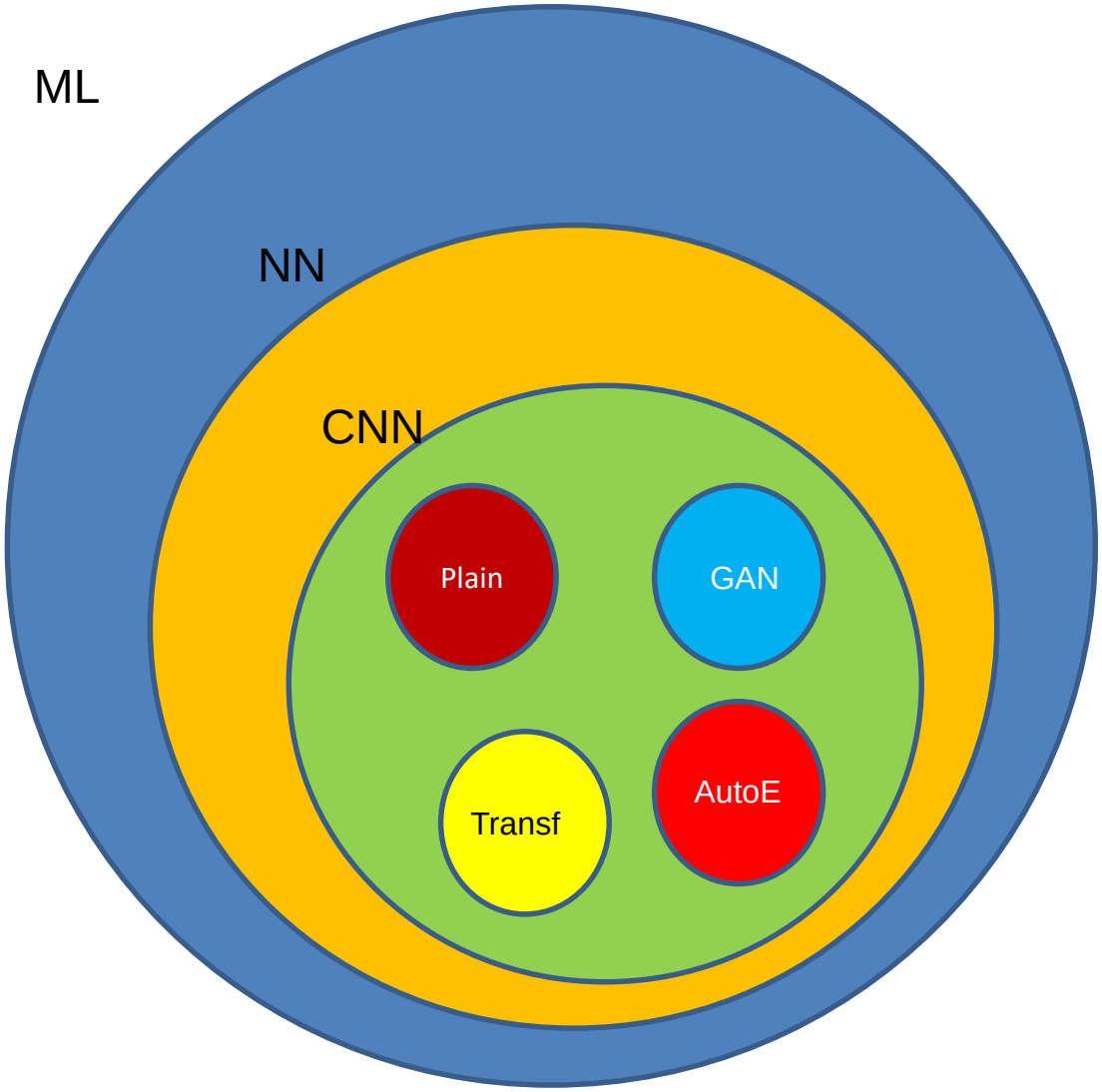


Nota: Las etiquetas de clase están en el archivo .csv este lo pueden leer desde matlab con la instrucción: labels= readtable('WormData.csv');

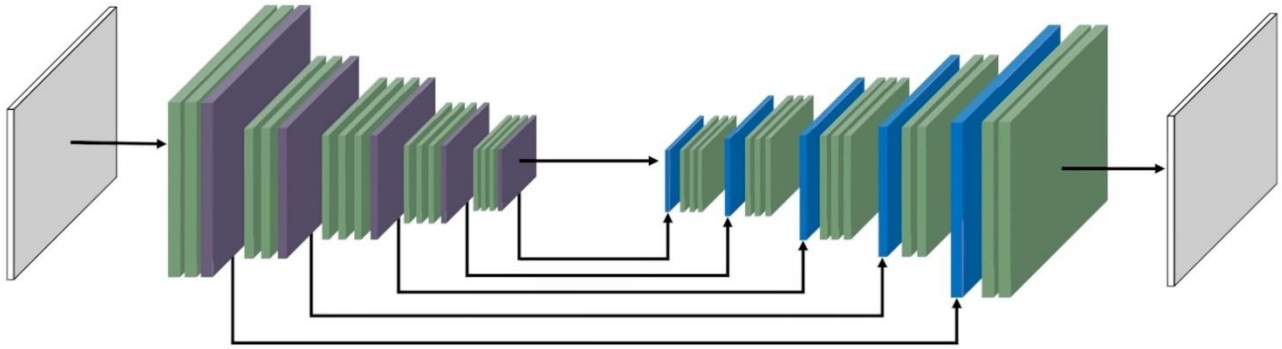
Convolutional Neural Networks

- CNN
  - Classification (Alexnet).
  - Regression (?).
- R-CNN
  - Localization (YOLO).
  - Segmentation (U-Net).
- Adversial
  - DCGAN.
  - cDCGAN.

Convolutional Neural Networks



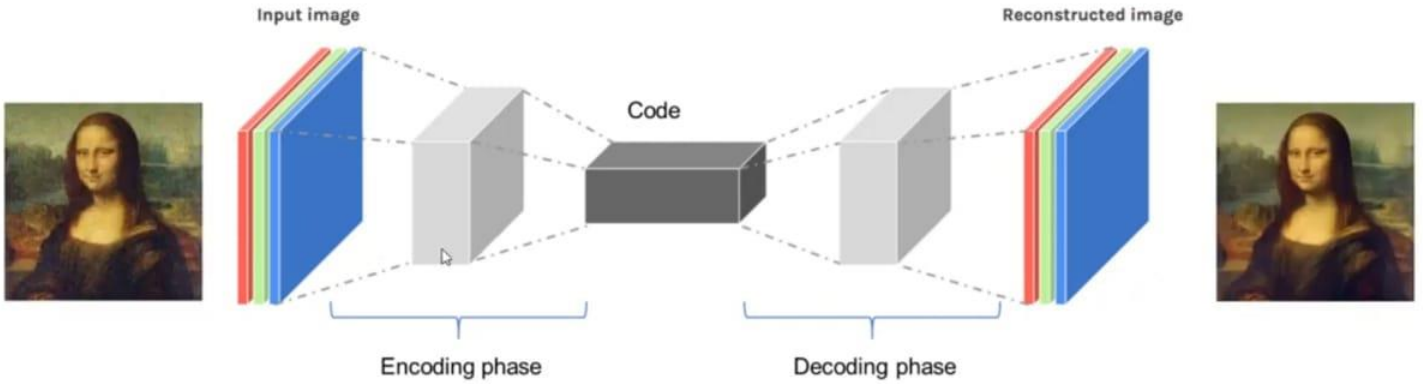
Encoder-decoder structure



Encoder *Decoder*

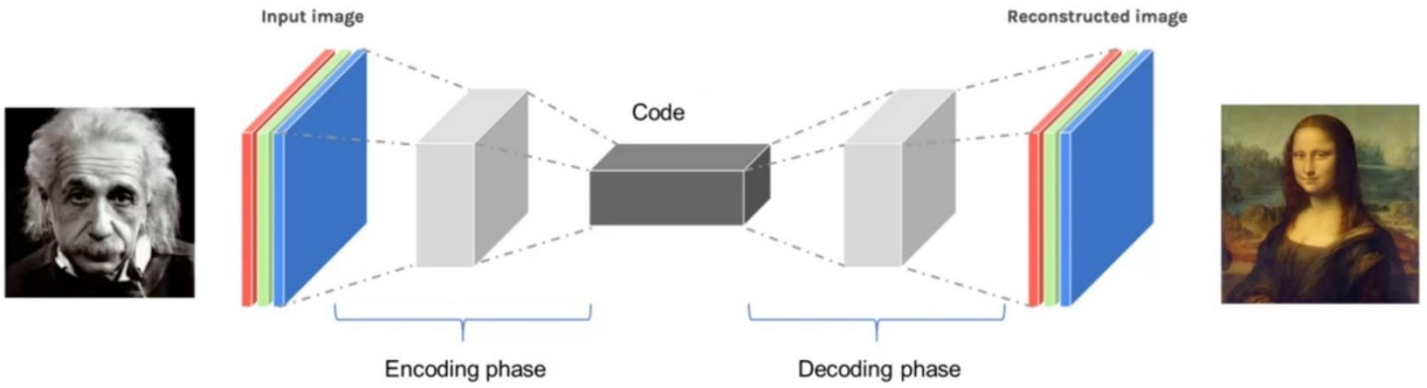
Autoencoder

Autoencoder Applications
Noise Reduction



Pix2Pix

Autoencoder Applications
Domain adaptation

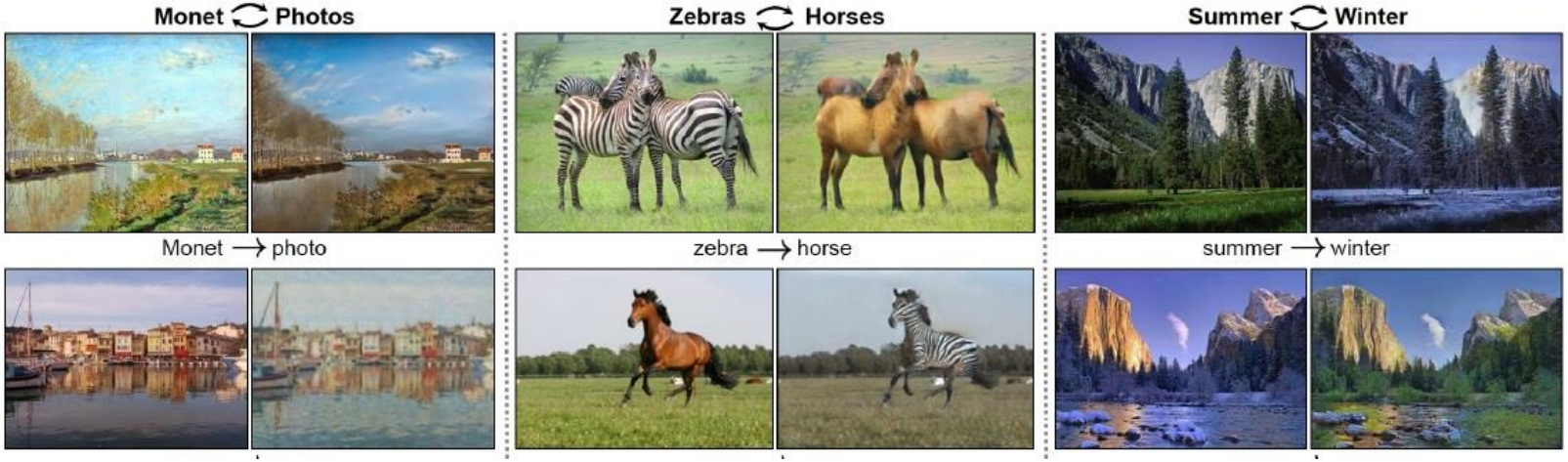


Animaciones sintéticas

- Deepfake.

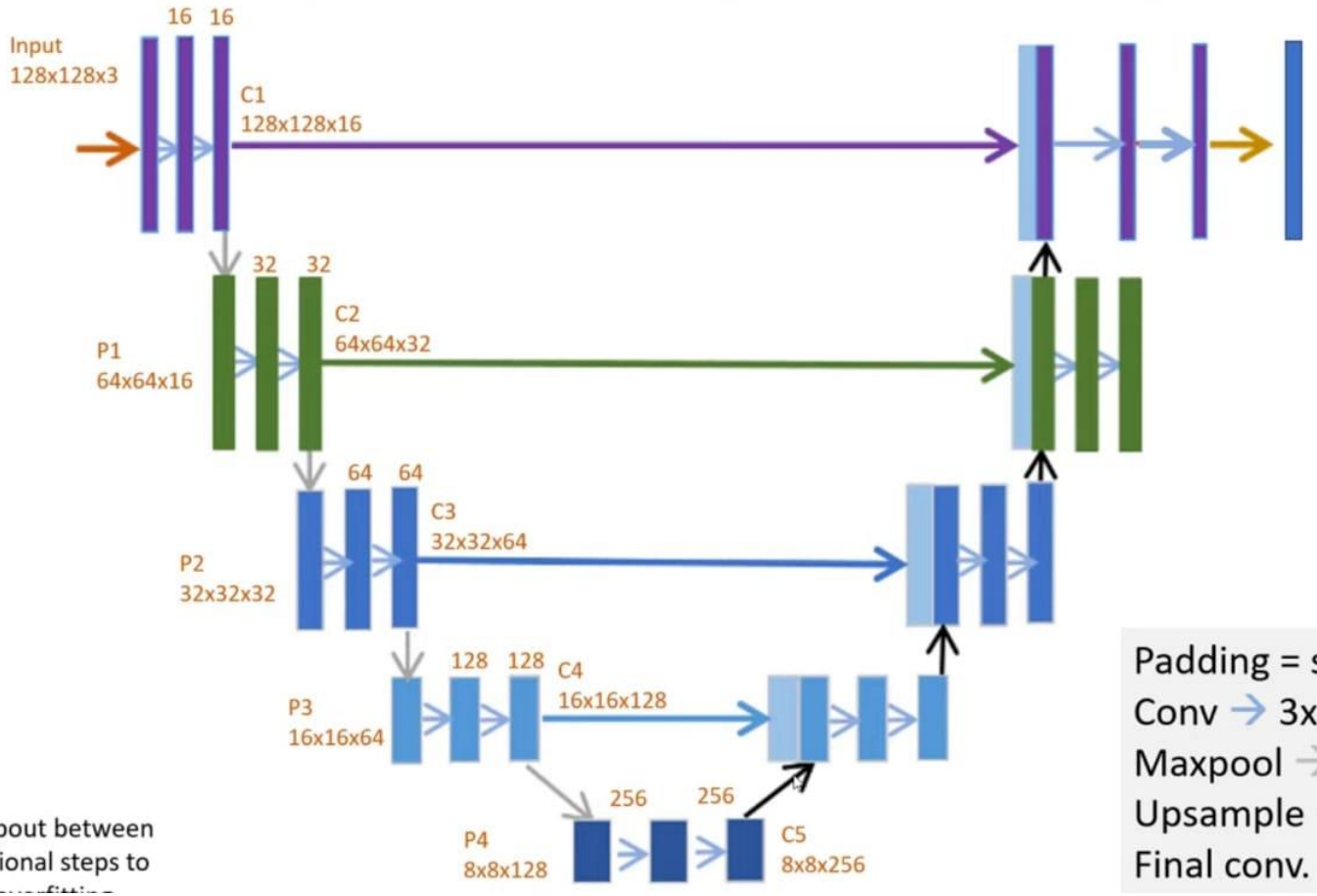
https://commons.wikimedia.org/wiki/File:Sw-face-swap.png

- Transferencia de estilo.



Jun-Yan Zhu*, Taesung Park*, Phillip Isola, and Alexei A. Efros. "Unpaired Image-to-Image Translation using Cycle-Consistent Adversarial Networks", in IEEE International Conference on Computer Vision (ICCV), 2017.

U-Net

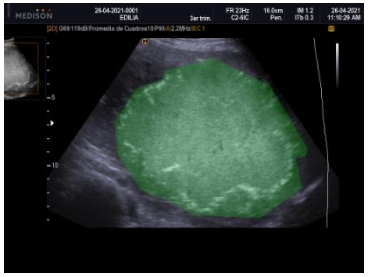
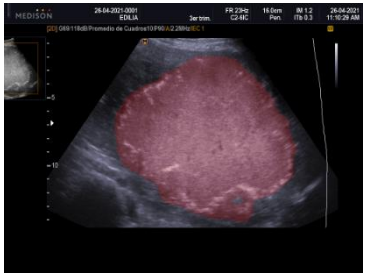


Also dropout between convolutional steps to

Padding = same
Conv → 3x3 ReLU
Maxpool → 2x2 (Stride=2)
Upsample → 2x2
Final conv. → 1x1

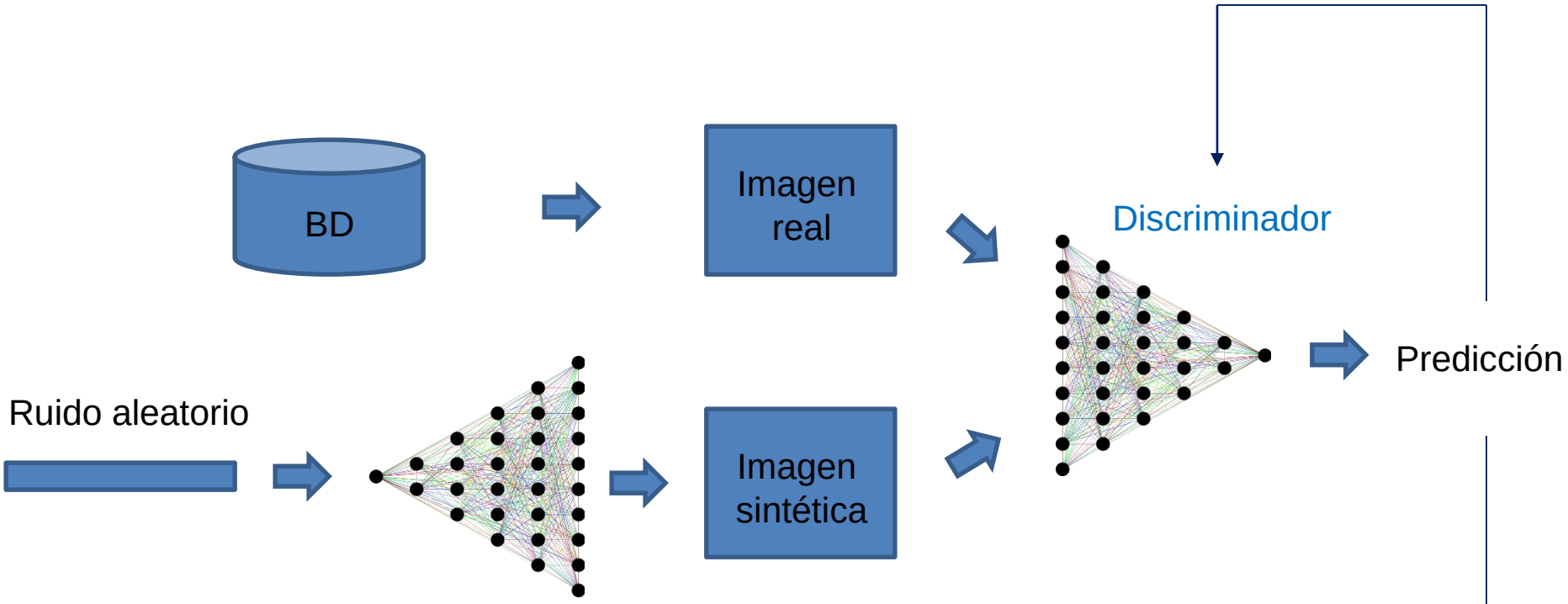
Segmentación de placenta

Tesis de maestría del Ing. José A. Fuentes Tomás.

Original	Groundtruth	Predicted
		
		
		

Redes generativas adversarias (GANs)

- Goodfellow, 2014.

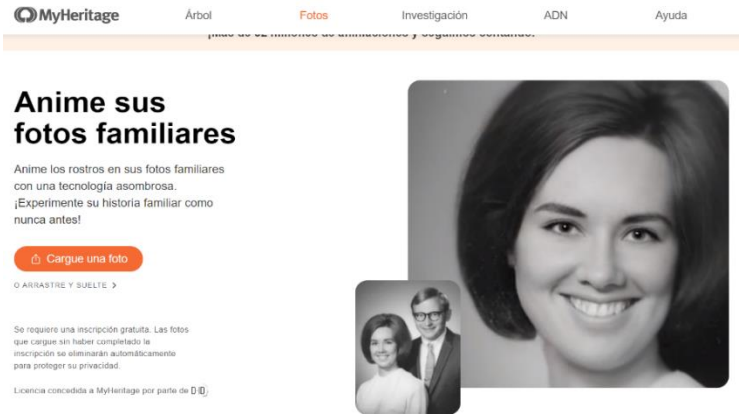


https://pixabay.com/es/illustrations/press-de-banca-lucha-vencidas-1013857/
https://pixabay.com/es/vectors/red-neural-pensamiento-mente-mental-3816319/

Aplicaciones

- Generación de imágenes sintéticas.

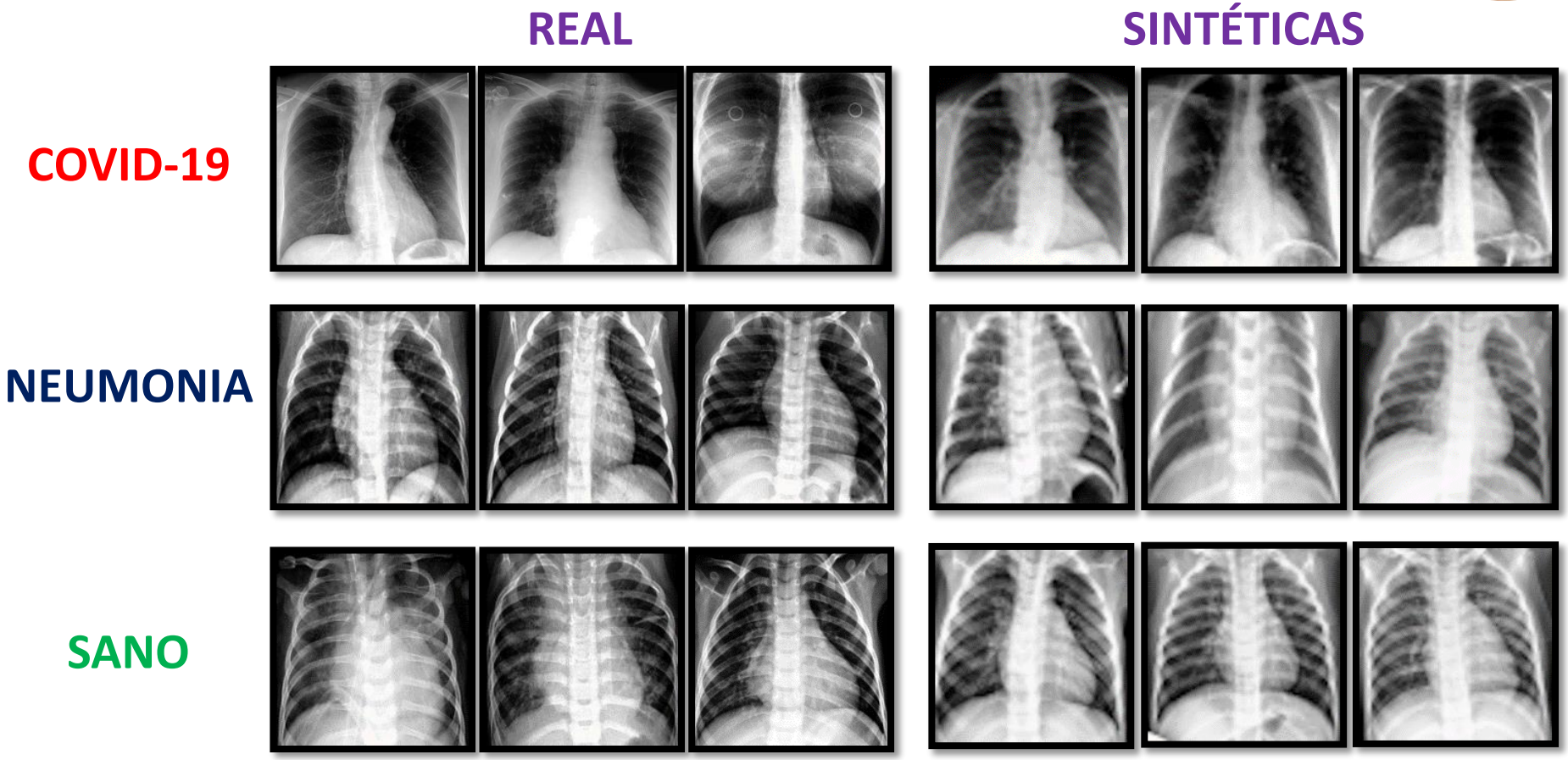
https://thispersondoesnotexist.com/



https://www.myheritage.es/deep-nostalgia

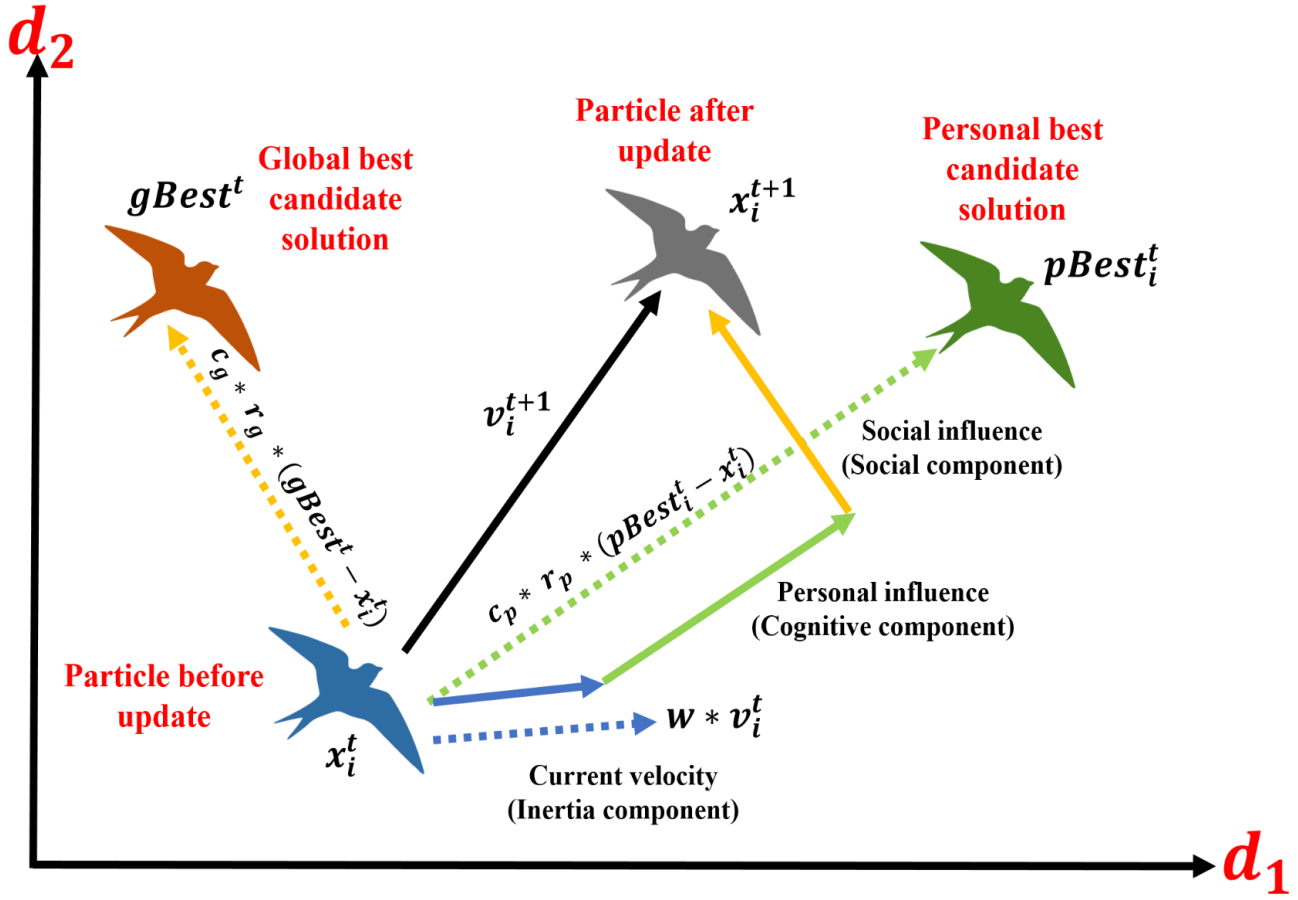
Síntesis de radiografías de torax

Tesis de maestría del Ing. Juan A. Rodríguez de la Cruz.



Material del Ing. Juan Antonio Rodriguez de la Cruz.

Optimización por enjambre de partículas



Material del MIA. Juan Antonio Rodriguez de la Cruz.

Síntesis de radiografías de torax

Mejora en la clasificación

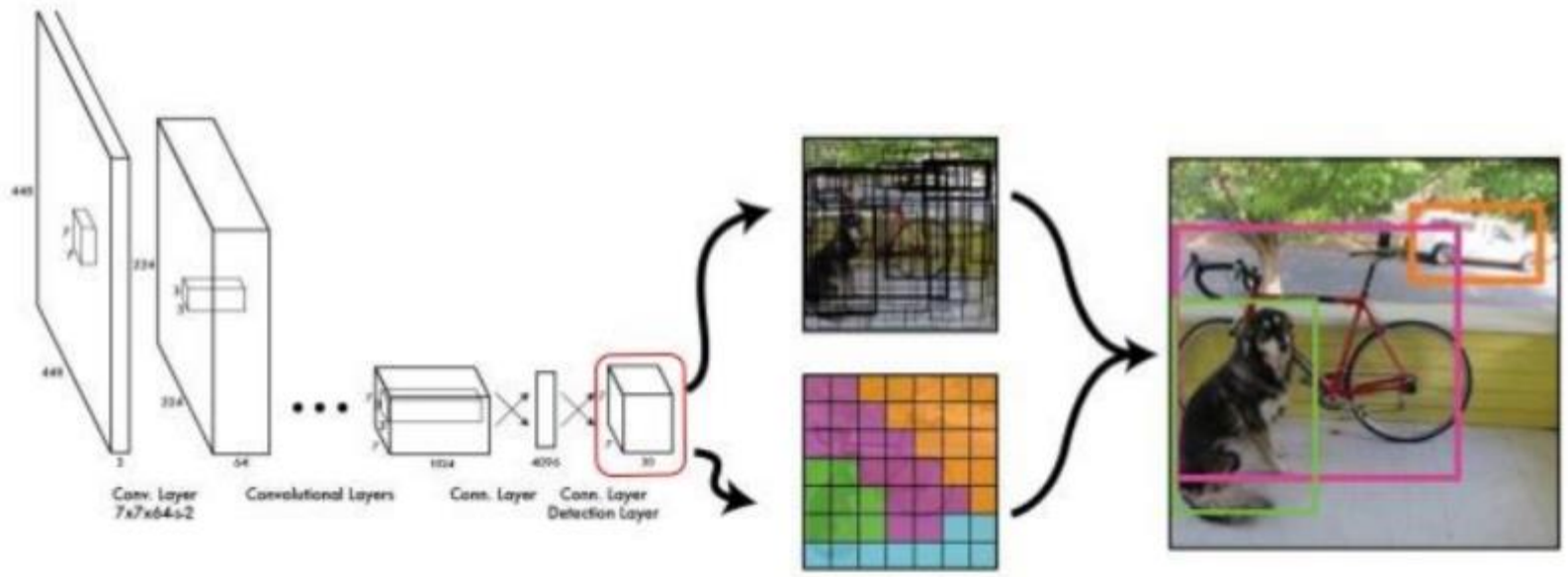
Datos	Classes	N° images	Exactitud
Desbalanceados	COVID-19	600 reales	72.3 ± 4.3
	No-COVID-19	1200 reales	
Balanceados	COVID-19	600 reales + 600 sintéticas	**80.4** ± 3.12
	No-COVID-19	1200 reales	

Juan-Antonio Rodríguez-de-la-Cruz, Héctor-Gabriel Acosta-Mesa and Efrén Mezura-Montes. Evolution of Generative Adversarial Networks using PSO for synthesis of COVID-19 Chest X-ray images. Accepted for publication in IEEE Congress on Evolutionary Computation (2021).

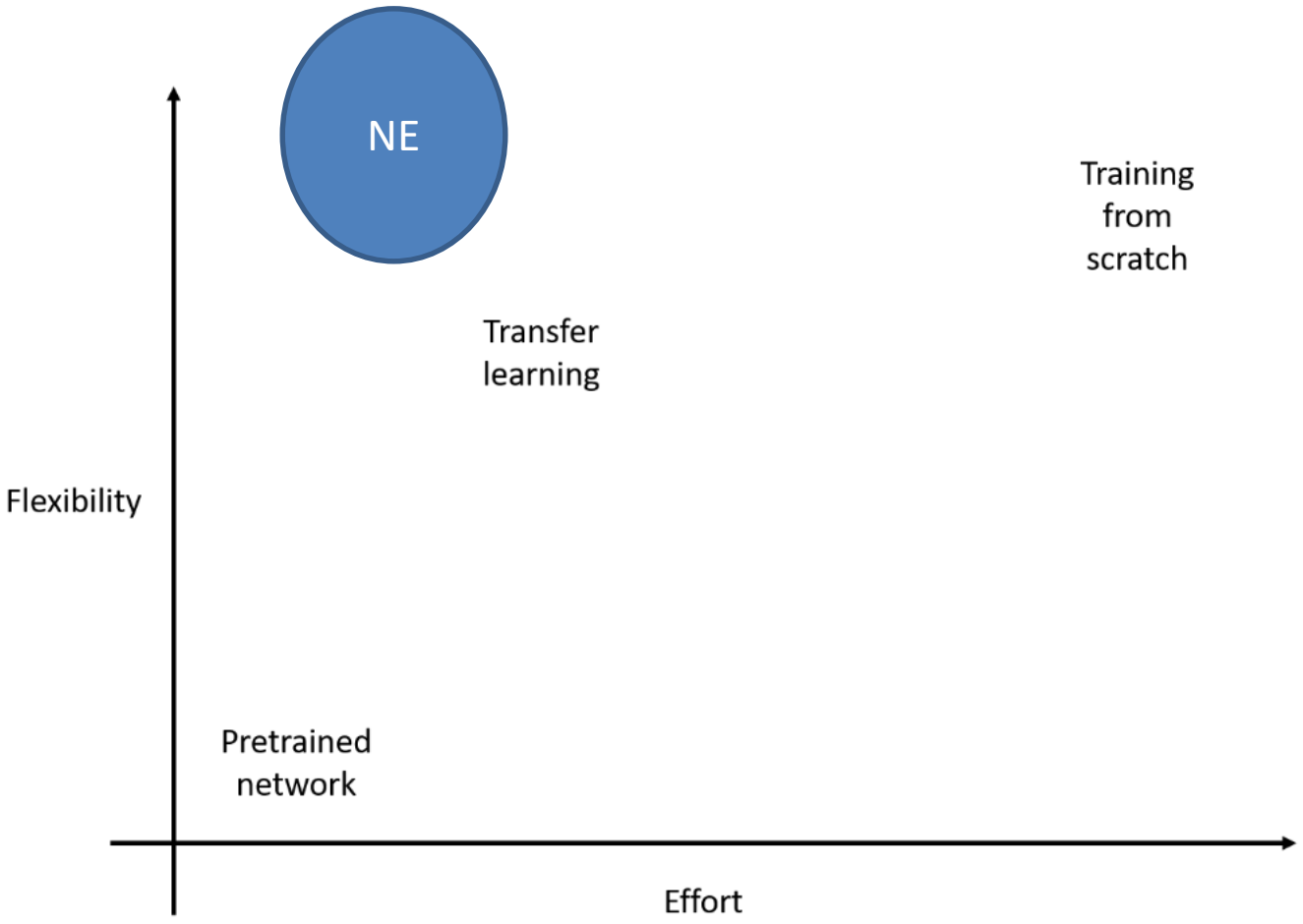
Juan-Antonio Rodríguez-de-la-Cruz, Héctor-Gabriel Acosta-Mesa, Efrén Mezura-Montes, Fernando Arámbula Cosío, Boris Escalante-Ramírez, and Jimena Olveres Montiel. Evolution of conditional-GANs for the synthesis of chest X-ray images. The 17th International Symposium on Medical Information Processing and Analysis (SIPAIM). 2021

YOLO

YOLO: You Only Look Once

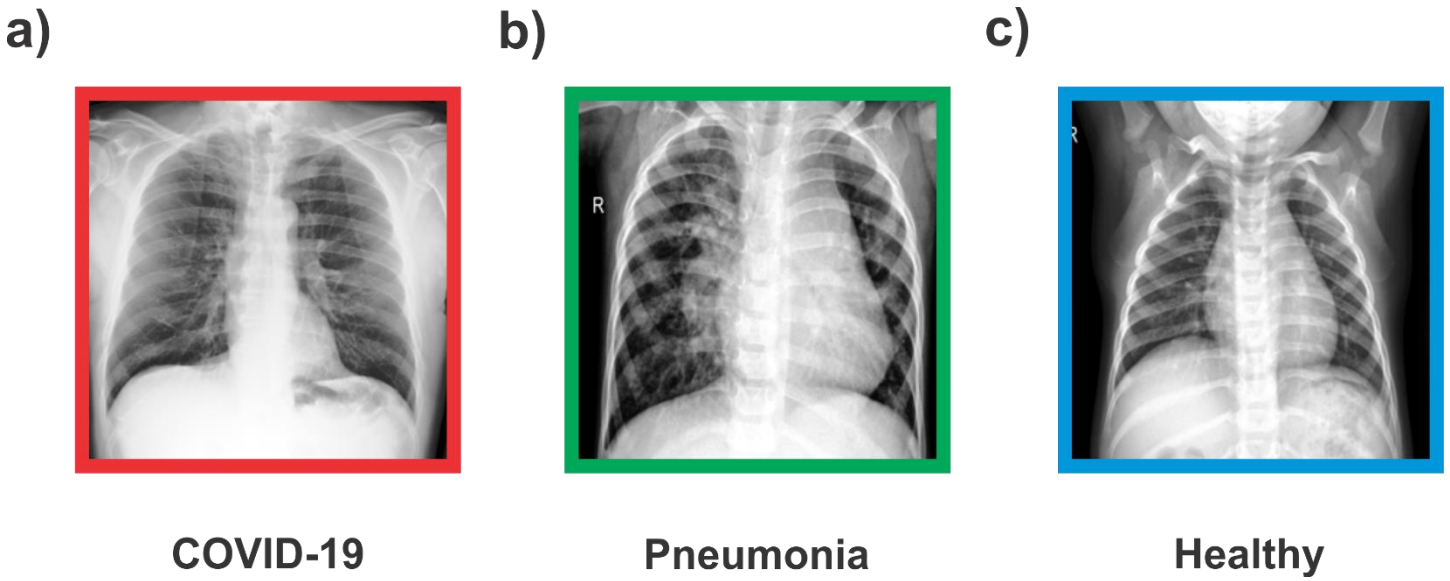


Convolutional Neural Networks



Clasificación de radiografías de tórax

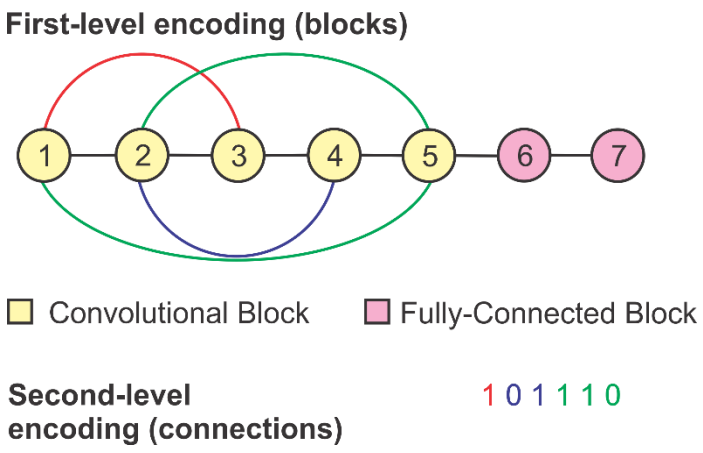
Tesis de maestría del Ing. Gustavo A. Vargas Hákim.



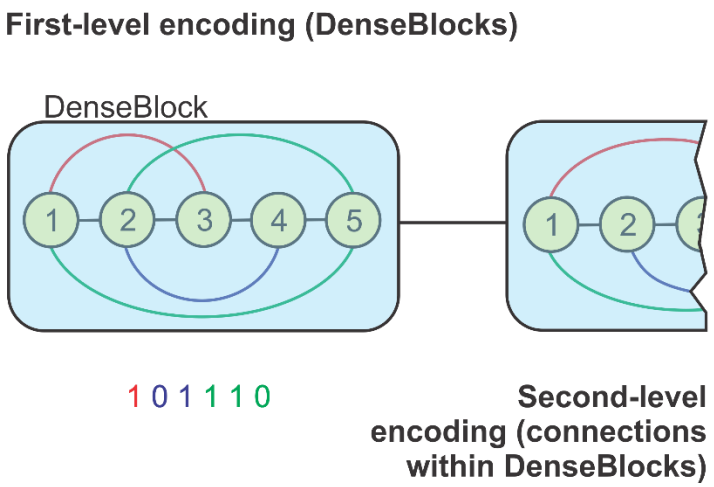
Imágenes obtenidas de:

- Cohen, J. P. et al. (2020). “COVID-19 Image Data Collection: Prospective Predictions Are the Future”. In: arXiv 2006-11988
- Mooney, P. (2017). *Chest X-Ray Images (Pneumonia).* URL: https://www.kaggle.com/paultimothymooney/chest-xray-pneumonia

Propuesta de codificación



Codificación propuesta*



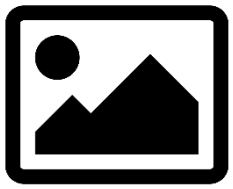
Codificación de Wang**

* Gustavo-Adolfo Vargas-Hákim, Efrén Mezura-Montes, Héctor-Gabriel Acosta-Mesa. A Review on Convolutional Neural Networks. Encodings for Neuroevolution. IEEE Transactionson Evolutionary Computation. Factor de impacto 11.16

** Wang, Y. Sun, et al. (2017). "A Hybrid GA-PSO Method for Evolving Architecture and Short Connections of Deep Convolutional Neural Networks". In: *Proceedings of the Pacific Rim International Conference on Artificial Intelligence.* Springer, pp. 650-663 DOI:10.1007/978-3-030-29894-4_52.

Datos utilizados

Colección de imágenes



2754 imágenes

- 918 COVID-19
- 918 bacterial/viral pneumonia
- 918 healthy

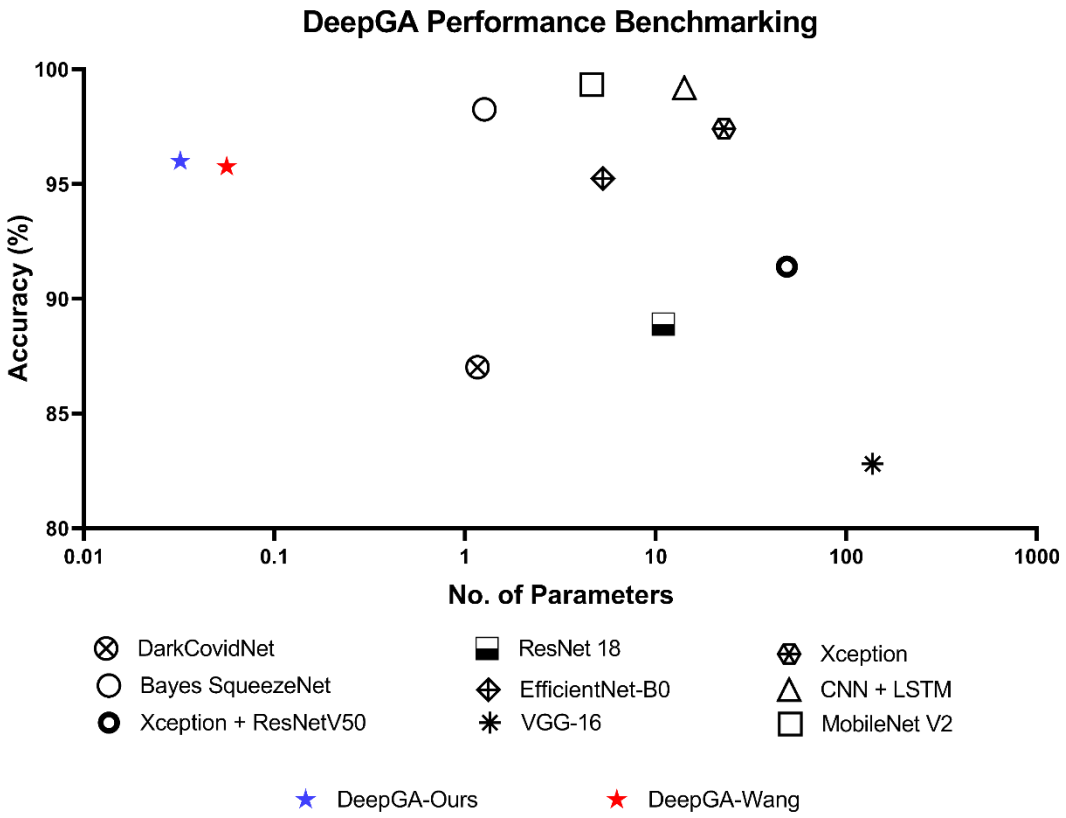
Cohen, J. et al. (2020). "COVID-19 Image Data Collection: Prospective Predictions Are the Future". In: *ArXiV 2006.11988,* URL: https://github.com/ieee8023/covidchestxray-dataset

Wang, L., A. Wong, et al. (2020). *Actualmed COVID-19 Chest X-ray Dataset Initiatives.* URL: https://github.com/agchung/Actualmed-COVID-chestxraydataset

Mooney, P. (2017). *Chest X-Ray Images (Pneumonia).* URL: https://www.kaggle.com/paultimothymooney/chest-xray-pneumonia

Resultados

Comparación con CNNs diseñadas a mano



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Material del Ing. Gustavo Adolfo Vargas Hákim.