

# Convolutional Neural Networks, an application in a radiology dataset

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Here we are supposed to present present the commands coded to train a neural network algorithm in order classify a dataset of X-Ray-Chest images, previously classified according with its diagnosed pathology.

## Libraries

```
In [1]: using Flux, Images, MLDatasets, Plots  
using Flux: crossentropy, onecold, onehotbatch, train!  
using LinearAlgebra, Random, Statistics  
using Images  
using TestImages  
using ImageIO  
using CSV  
using DataFrames
```

```
In [116...]: using ImageShow  
using MosaicViews
```

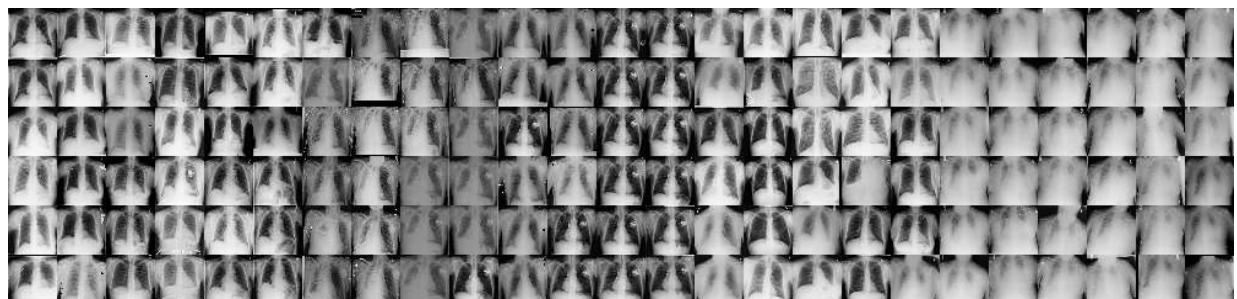
## Importing Dataset

The database is a portion of an open medical imaging dataset, this can be viewed from <https://www.v7labs.com/open-datasets/chestx-ray14>.

```
In [3]: url = "C:\\\\Users\\\\santi\\\\OneDrive\\\\Escritorio\\\\Matematicas VII\\\\Numerico\\\\ProyectoFi  
cd(url)  
base_path = pwd()  
names_ = readdir(base_path)[1:4998]  
size = length(names_)  
images = [load(names_[k]) for k in 1:size]; #Here we saved the images information
```

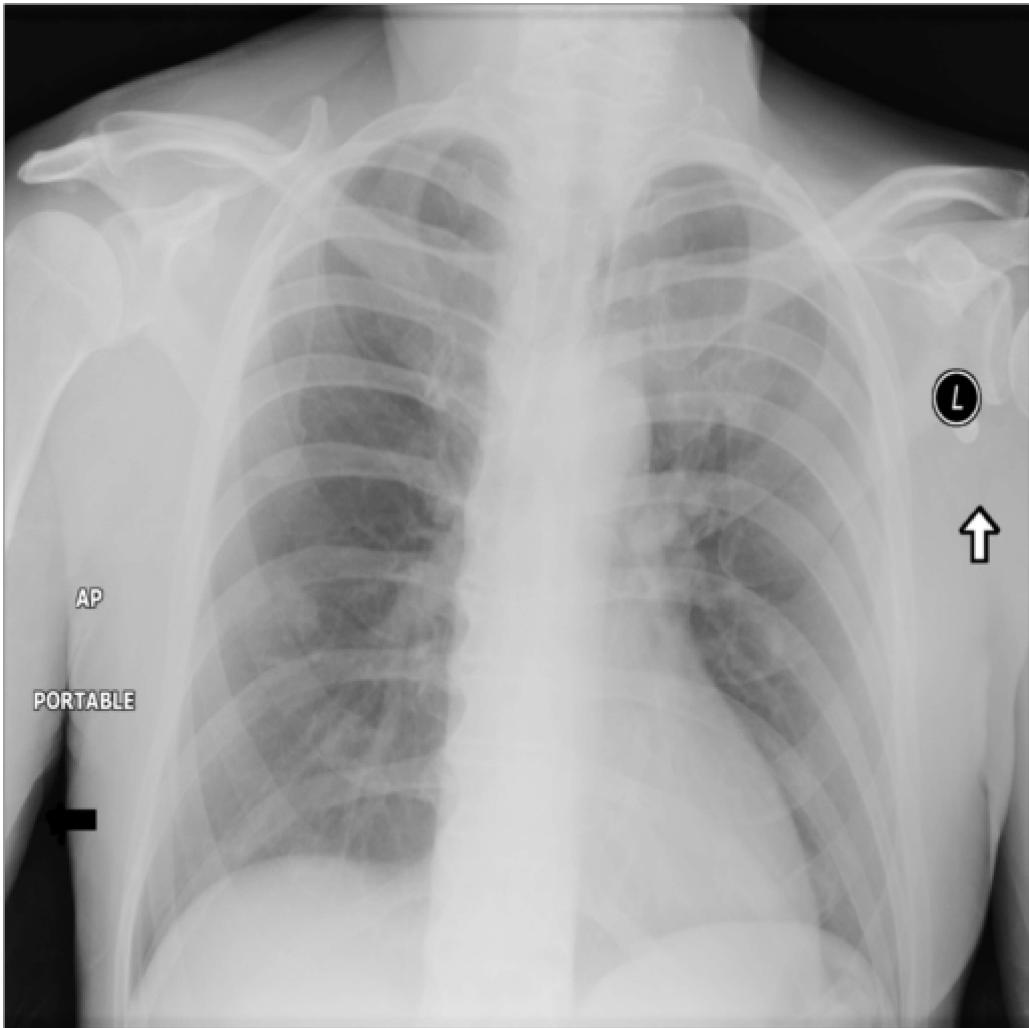
```
In [141...]: mosaicview(resized_images[1:150], nrow=6)
```

Out[141...]



```
In [4]: test_image = images[12]
```

Out[4]:



In [ ]:

In [ ]:

## Dataset treatment

At first, we have done an image processing and filtering in order to give better parameters to the model. So we did a resizing (from 1024x1024 to 40x40), a gray-scale filtering (since some images -71- were processed by Julia as RGB images) in order to convert these images to `Float64` Matrices by an easier way.

We attempted also apply a convolutional filter, namely, a Laplacian Kernel (`Kernel.Laplacian()`) and we got nice results for some images, but unfortunately we couldn't pass this filter to the whole 4998 images (The Jupyter Kernel crashed).

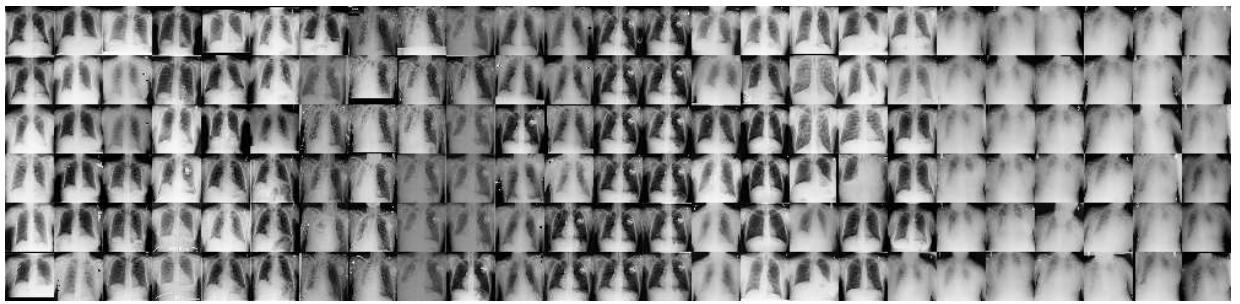
In [5]:

```
resized_images = [imresize(images[k], (40,40)) for k in 1:size];
```

In [6]:

```
mosaic(resized_images[1:150], nrow=6)
```

Out[6]:



We apply a convolution filter:

```
In [7]: convolved_image = imfilter(images[200], Kernel.gaussian(3))
```

Out[7]:



```
In [8]: floated_images = [Float64.(Gray.(resized_images[k])) for k in 1:size]; #FINALLY!!!!
```

Here we imported the dataset with the correct pathology-classification. But also we imported a dataset with a numerical value associated with each image-name instead of its pathology name

```
In [9]: df = DataFrame(CSV.File("C:\\\\Users\\\\santi\\\\OneDrive\\\\Escritorio\\\\Matematicas VII\\\\Nu
```

```
| Warning: thread = 1 warning: only found 9 / 11 columns around data row: 16916. Fil  
|   ling remaining columns with `missing`  
└ @ CSV C:\\Users\\santi\\.julia\\packages\\CSV\\jFicn\\src\\file.jl:578
```

```
In [10]: database = DataFrame(CSV.File("C:\\\\Users\\\\santi\\\\OneDrive\\\\Escritorio\\\\Matematicas V
```

Out[10]: 5,000 rows × 12 columns (omitted printing of 6 columns)

	Image Index	Finding Labels	Follow-up #	Patient ID	Patient Age	Patient Gender
	String31	Int64	Int64	Int64	Int64	String1
1	00000001_000.png	2	0	1	57	M
2	00000001_001.png	11	1	1	58	M
3	00000001_002.png	3	2	1	58	M
4	00000002_000.png	0	0	2	80	M
5	00000003_001.png	14	0	3	74	F
6	00000003_002.png	14	1	3	75	F
7	00000003_003.png	4	2	3	76	F
8	00000003_004.png	14	3	3	77	F
9	00000003_005.png	14	4	3	78	F
10	00000003_006.png	14	5	3	79	F
11	00000003_007.png	14	6	3	80	F
12	00000003_000.png	14	7	3	81	F
13	00000004_000.png	5	0	4	82	M
14	00000005_000.png	0	0	5	69	F
15	00000005_001.png	0	1	5	69	F
16	00000005_002.png	0	2	5	69	F
17	00000005_003.png	0	3	5	69	F
18	00000005_004.png	0	4	5	70	F
19	00000005_005.png	0	5	5	70	F
20	00000005_006.png	4	6	5	70	F
21	00000005_007.png	4	7	5	70	F
22	00000006_000.png	0	0	6	81	M
23	00000007_000.png	0	0	7	82	M
24	00000008_000.png	2	0	8	68	F
25	00000008_001.png	0	1	8	70	F
26	00000008_002.png	6	2	8	72	F
27	00000009_000.png	11	0	9	72	M
28	00000010_000.png	4	0	10	84	F
29	00000011_000.png	3	0	11	74	M
30	00000011_001.png	0	1	11	74	M
:	:	:	:	:	:	:

In [11]:

```
names = database[!,1][1:4998]
labels = database[!,2][1:4998]
```

```
Out[11]: 4998-element Vector{Int64}:
 2
11
 3
 0
14
14
 4
14
14
14
14
14
14
14
 5
  :
 6
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
 0
```

In the following rows you can view how we prepare a raw dataset.

```
In [12]: model_images = floated_images;
```

```
In [13]: A = fill(0.0, 40, 40, 4998); #This matrix is supposed to be used to convert model i
```

```
In [14]:  
for imag in 1:size  
    current_image = model_images[imag]  
    for col in 1:40  
        for row in 1:40  
            A[row, col, imag] = current_image[row, col]  
        end  
    end  
end
```

```
In [15]: model images in array form = A;
```

## Breaking the dataset up

```
In [89]: X_train_raw, y_train_raw = model_images_in_array_form[:, :, 1:4000], labels[1:4000];
X_test_raw, y_test_raw = model_images_in_array_form[:, :, 4001:4998], labels[4001:4998]
```

```
In [90]: X_train = Flux.flatten(X_train_raw);  
X_test = Flux.flatten(X_test_raw);
```

```
In [91]: #anchorbatch encodes label
```

```
y_train = onehotbatch(y_train_raw, 0:14)
y_test = onehotbatch(y_test_raw, 0:14)
```

# Building the model

We coded a deep neural network with three layers

1. The first, with  $40 \times 40$  nodes.
  2. The intermediate one, with 32 nodes and the activation function ReLu.
  3. The last one associated with the 15 possible labels.

```
In [99]: model = Chain(  
    Dense(40*40, 32, relu),  
    Dense(32, 15),  
    softmax  
)
```

```
Out[99]: Chain(  
    Dense(1600 => 32, relu),           # 51_232 parameters  
    Dense(32 => 15),                  # 495 parameters  
    NNlib.softmax,  
)          # Total: 4 arrays, 51_727 parameters, 202.309 KiB.
```

```
In [100...]: #define loss function  
loss(x, y) = crossentropy(model(x), y)  
  
Out[100...]: loss (generic function with 1 method)
```

```
In [101...]: #track parameters  
ps = Flux.params(  
    ps
```

```
In [102...]: #select optimizer  
learning_rate = 0.01  
opt = ADAM(learning_rate)
```

```
Out[102...]: ADAM(0.01, (0.9, 0.999), 1.0e-8, IdDict{Any, Any}())
```

## Training the model

We trained our neural network model with a total of 1000 epochs, a learning rate of 0.05 and we chose the optimizer ADAM .

```
In [104...]: #train model  
  
loss_history = []  
  
epochs = 1000  
  
for epoch in 1:epochs  
    #train model  
    train!(loss, ps, [(X_train, y_train)], opt)  
    #print report  
    train_loss = loss(X_train, y_train)  
    push!(loss_history, train_loss)  
    println("Epoch = $epoch : Training Loss = $train_loss")  
end
```

```
Epoch = 1 : Training Loss = 1.7387880755936103  
Epoch = 2 : Training Loss = 1.7408975676599499  
Epoch = 3 : Training Loss = 1.7381098720058725  
Epoch = 4 : Training Loss = 1.7370849853406984  
Epoch = 5 : Training Loss = 1.7387913103621992  
Epoch = 6 : Training Loss = 1.7366176599628071  
Epoch = 7 : Training Loss = 1.73579576235339  
Epoch = 8 : Training Loss = 1.7369257352981473  
Epoch = 9 : Training Loss = 1.735229062878666  
Epoch = 10 : Training Loss = 1.7345369632577619  
Epoch = 11 : Training Loss = 1.7352960720500155  
Epoch = 12 : Training Loss = 1.7338343129017388  
Epoch = 13 : Training Loss = 1.733445480820083  
Epoch = 14 : Training Loss = 1.7338214163606964  
Epoch = 15 : Training Loss = 1.732592630182069  
Epoch = 16 : Training Loss = 1.7323718947013538  
Epoch = 17 : Training Loss = 1.7324625546861452  
Epoch = 18 : Training Loss = 1.7314059212503048  
Epoch = 19 : Training Loss = 1.7313473012677492  
Epoch = 20 : Training Loss = 1.7311598136265507  
Epoch = 21 : Training Loss = 1.730312576039947  
Epoch = 22 : Training Loss = 1.7303141606000356  
Epoch = 23 : Training Loss = 1.7299278861450484  
Epoch = 24 : Training Loss = 1.7293132162454288  
Epoch = 25 : Training Loss = 1.729310452215494  
Epoch = 26 : Training Loss = 1.7288135760570695  
Epoch = 27 : Training Loss = 1.7284319686088812  
Epoch = 28 : Training Loss = 1.7283569366718312  
Epoch = 29 : Training Loss = 1.72785270333404  
Epoch = 30 : Training Loss = 1.727667397226826  
Epoch = 31 : Training Loss = 1.727473767995175  
Epoch = 32 : Training Loss = 1.7270663906450971  
Epoch = 33 : Training Loss = 1.7269721638201232
```

Epoch = 34 : Training Loss = 1.7266808622105683  
Epoch = 35 : Training Loss = 1.7264203124289847  
Epoch = 36 : Training Loss = 1.726306180597891  
Epoch = 37 : Training Loss = 1.7259948553740063  
Epoch = 38 : Training Loss = 1.7258493669488733  
Epoch = 39 : Training Loss = 1.7256571944415775  
Epoch = 40 : Training Loss = 1.7254094716306785  
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Epoch = 45 : Training Loss = 1.7245022682344524  
Epoch = 46 : Training Loss = 1.724369380918704  
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Epoch = 49 : Training Loss = 1.7238371146410332  
Epoch = 50 : Training Loss = 1.7236454726910824  
Epoch = 51 : Training Loss = 1.723501990378251  
Epoch = 52 : Training Loss = 1.7233145339467024  
Epoch = 53 : Training Loss = 1.7231552313421412  
Epoch = 54 : Training Loss = 1.7229917910950616  
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Epoch = 211 : Training Loss = 1.6973053168522054  
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Epoch = 222 : Training Loss = 1.6953524211622157  
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Epoch = 224 : Training Loss = 1.6949939914877976  
Epoch = 225 : Training Loss = 1.6948143884695723

Epoch = 226 : Training Loss = 1.6946345270300427  
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Epoch = 228 : Training Loss = 1.6942740293251606  
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Epoch = 230 : Training Loss = 1.6939125928069156  
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Epoch = 237 : Training Loss = 1.6926410881456904  
Epoch = 238 : Training Loss = 1.6924585632803437  
Epoch = 239 : Training Loss = 1.6922760528315282  
Epoch = 240 : Training Loss = 1.692093850713501  
Epoch = 241 : Training Loss = 1.6919125048285921  
Epoch = 242 : Training Loss = 1.691733216624736  
Epoch = 243 : Training Loss = 1.6915587761939805  
Epoch = 244 : Training Loss = 1.6913953138597062  
Epoch = 245 : Training Loss = 1.6912592517965095  
Epoch = 246 : Training Loss = 1.6911869549785368  
Epoch = 247 : Training Loss = 1.6912912321104532  
Epoch = 248 : Training Loss = 1.6918076721448856  
Epoch = 249 : Training Loss = 1.6936231400071038  
Epoch = 250 : Training Loss = 1.6980015168534968  
Epoch = 251 : Training Loss = 1.7114424383291111  
Epoch = 252 : Training Loss = 1.7270770640711275  
Epoch = 253 : Training Loss = 1.759441736117487  
Epoch = 254 : Training Loss = 1.7139911778613968  
Epoch = 255 : Training Loss = 1.6898218720956353  
Epoch = 256 : Training Loss = 1.7018805365479275  
Epoch = 257 : Training Loss = 1.7137257935040635  
Epoch = 258 : Training Loss = 1.7065714772239136  
Epoch = 259 : Training Loss = 1.6892185649844844  
Epoch = 260 : Training Loss = 1.702786674288981  
Epoch = 261 : Training Loss = 1.7135879530947968  
Epoch = 262 : Training Loss = 1.6907384245643884  
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Epoch = 994 : Training Loss = 1.6253632276005872
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Epoch = 997 : Training Loss = 1.6262645695241427
Epoch = 998 : Training Loss = 1.6307855371569557
Epoch = 999 : Training Loss = 1.637306810555482
Epoch = 1000 : Training Loss = 1.6357489380318788
```

```
In [105...]  
y_hat_raw = model(X_test)  
y_hat = onecold(y_hat_raw) .-1  
y = y_test_raw #Labelled data  
mean(y_hat .== y)
```

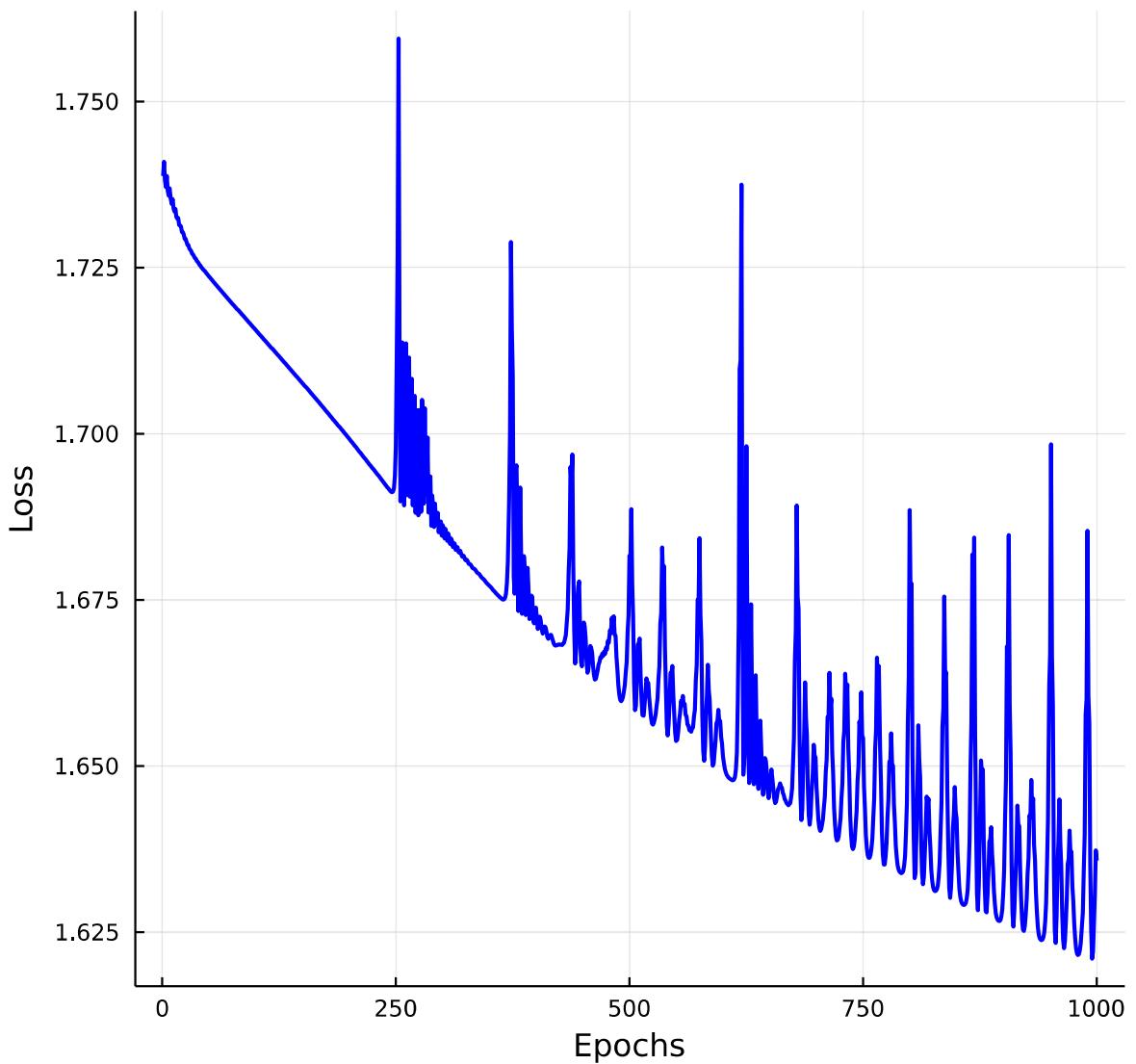
```
Out[105...]  
0.5681362725450901
```

```
In [113...]  
#plot loss  
gr(size = (600,600))  
#plot Learning curve  
p_l_curve = plot(1:epochs, loss_history,  
    xlabel = "Epochs",  
    ylabel = "Loss",  
    title = "Learning Curve - Radiology data",  
    legend = false,  
    color = :blue,  
    linewidth = 2  
)
```

*#Notice that this plot doesn't correspond exactly with the one reported previously.*

```
Out[113...]
```

## Learning Curve - Radiology data



Finally, we have gotten a loss of 1.635 from the model and we could clasify a %56.8 with success.