Ingeniería en Robótica y Sistemas Digitales

TE3002B.501

Implementación de Robótica Inteligente

Actividad

Entrenamiento de redes neuronales

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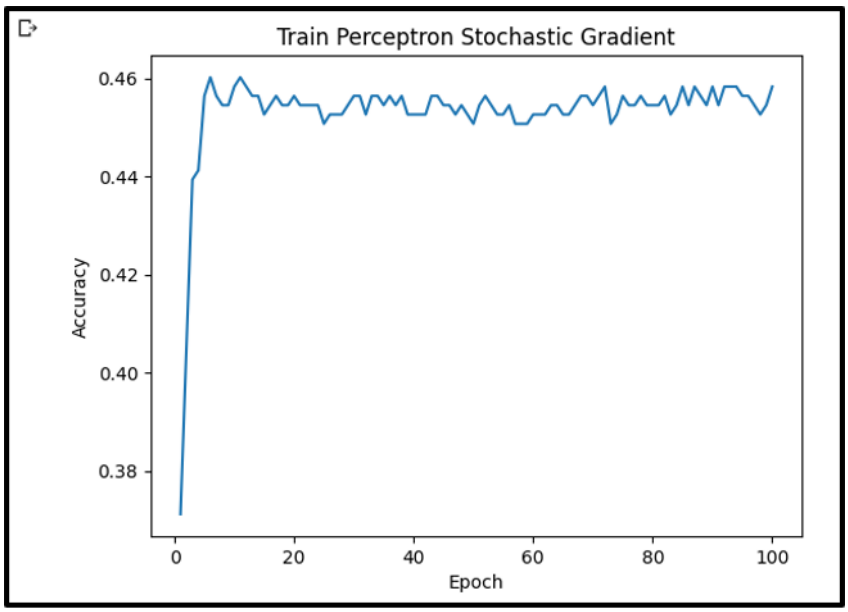
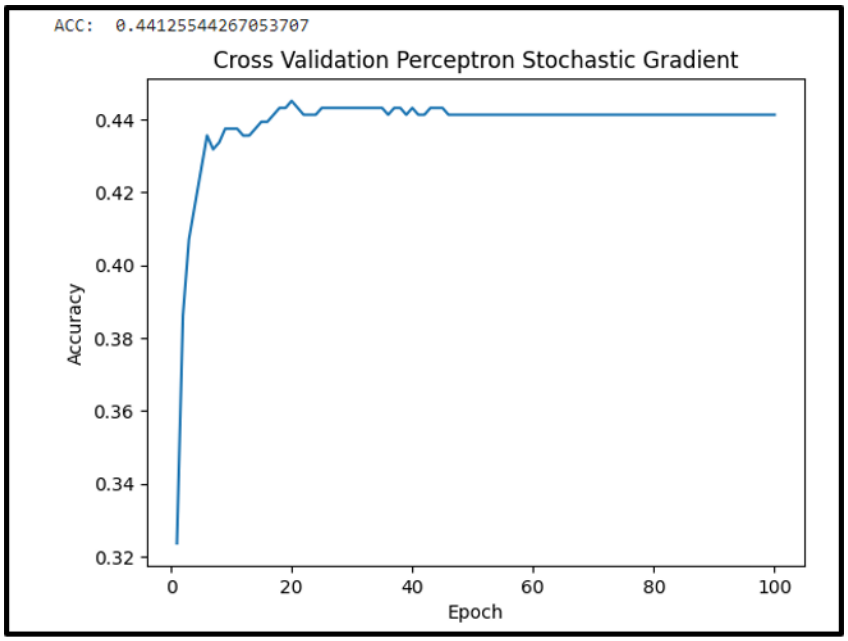
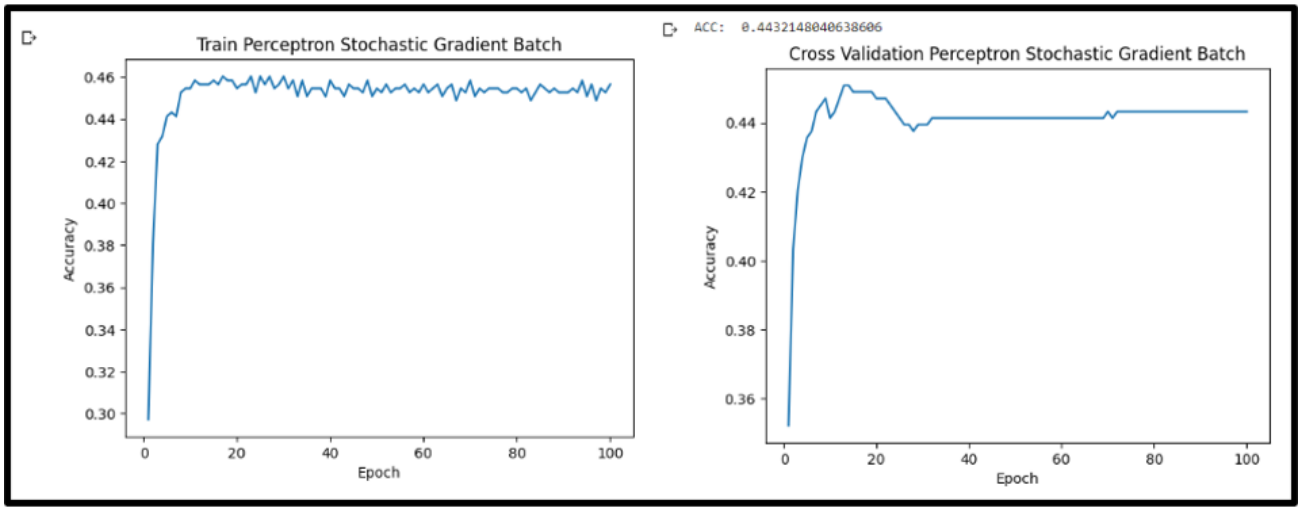
Ejercicio 1

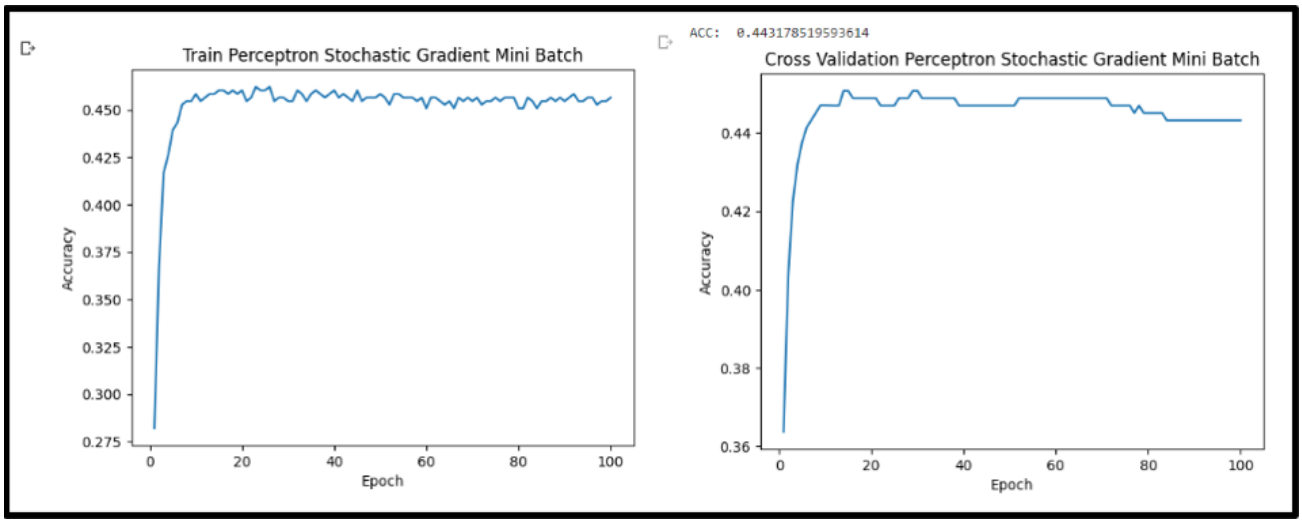
- **1.1**



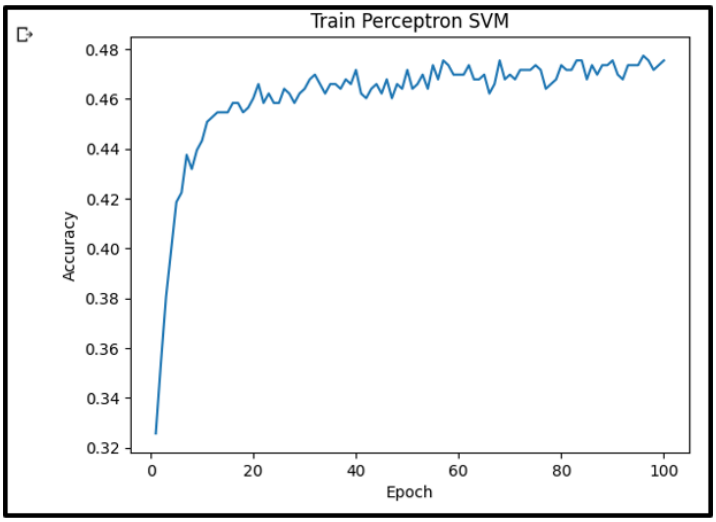


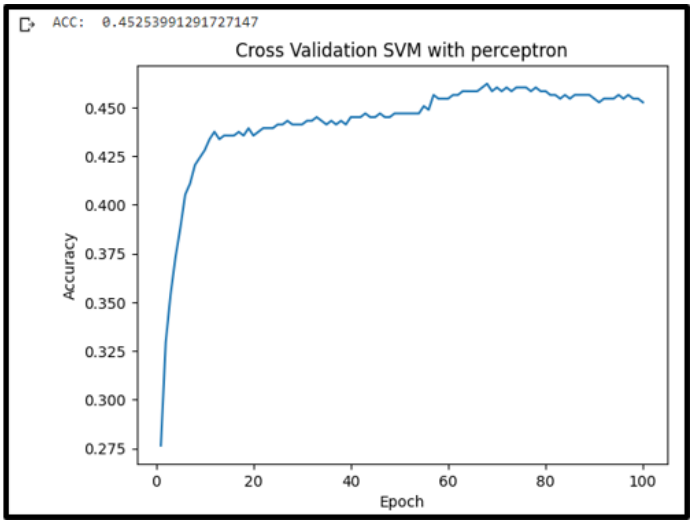
- **1.2**





- **1.3**





Link a colab: https://colab.research.google.com/drive/13hlSeABBB68kyu9xi_ga37dNvvrg-SOf?usp=sharing

Ejercicio 2

- **2.1**

```
Epoch 1/100
30/30 [==============================] - 1s 2ms/step - loss: 29039.9941
Epoch 2/100
30/30 [==============================] - 0s 2ms/step - loss: 28967.6484
Epoch 3/100
30/30 [==============================] - 0s 2ms/step - loss: 28853.5410
Epoch 4/100
30/30 [==============================] - 0s 2ms/step - loss: 28672.6445
Epoch 5/100
30/30 [==============================] - 0s 2ms/step - loss: 28384.1465
Epoch 6/100
30/30 [==============================] - 0s 2ms/step - loss: 27955.9395
Epoch 7/100
30/30 [==============================] - 0s 2ms/step - loss: 27348.5918
Epoch 8/100
30/30 [==============================] - 0s 2ms/step - loss: 26561.5234
Epoch 9/100
30/30 [==============================] - 0s 2ms/step - loss: 25585.0391
Epoch 10/100
30/30 [==============================] - 0s 2ms/step - loss: 24421.0391
Epoch 11/100
30/30 [==============================] - 0s 2ms/step - loss: 23081.7969
Epoch 12/100
30/30 [==============================] - 0s 3ms/step - loss: 21577.6094
Epoch 13/100
30/30 [==============================] - 0s 3ms/step - loss: 19932.1719
```

```
Epoch 14/100
30/30 [==============================] - 0s 4ms/step - loss: 18198.1484
Epoch 15/100
30/30 [==============================] - 0s 3ms/step - loss: 16415.8828
Epoch 16/100
30/30 [==============================] - 0s 3ms/step - loss: 14645.0332
Epoch 17/100
30/30 [==============================] - 0s 5ms/step - loss: 12924.8799
Epoch 18/100
30/30 [==============================] - 0s 4ms/step - loss: 11287.3672
Epoch 19/100
30/30 [==============================] - 0s 2ms/step - loss: 9820.5068
Epoch 20/100
30/30 [==============================] - 0s 2ms/step - loss: 8499.7480
Epoch 21/100
30/30 [==============================] - 0s 2ms/step - loss: 7392.5391
Epoch 22/100
30/30 [==============================] - 0s 2ms/step - loss: 6492.3794
Epoch 23/100
30/30 [==============================] - 0s 2ms/step - loss: 5790.4287
Epoch 24/100
30/30 [==============================] - 0s 2ms/step - loss: 5238.9907
Epoch 25/100
30/30 [==============================] - 0s 2ms/step - loss: 4853.0605
Epoch 26/100
30/30 [==============================] - 0s 2ms/step - loss: 4577.1255
```

```
Epoch 27/100
30/30 [==============================] - 0s 2ms/step - loss: 4386.1040
Epoch 28/100
30/30 [==============================] - 0s 2ms/step - loss: 4256.1543
Epoch 29/100
30/30 [==============================] - 0s 2ms/step - loss: 4165.7202
Epoch 30/100
30/30 [==============================] - 0s 2ms/step - loss: 4094.8835
Epoch 31/100
30/30 [==============================] - 0s 2ms/step - loss: 4046.5735
Epoch 32/100
30/30 [==============================] - 0s 2ms/step - loss: 4002.3828
Epoch 33/100
30/30 [==============================] - 0s 2ms/step - loss: 3963.6931
Epoch 34/100
30/30 [==============================] - 0s 2ms/step - loss: 3929.5854
Epoch 35/100
30/30 [==============================] - 0s 2ms/step - loss: 3896.0837
Epoch 36/100
30/30 [==============================] - 0s 2ms/step - loss: 3866.8103
Epoch 37/100
30/30 [==============================] - 0s 2ms/step - loss: 3842.7112
Epoch 38/100
30/30 [==============================] - 0s 2ms/step - loss: 3808.0872
Epoch 39/100
30/30 [==============================] - 0s 2ms/step - loss: 3780.4302
```

```
Epoch 40/100
30/30 [==============================] - 0s 2ms/step - loss: 3755.7415
Epoch 41/100
30/30 [==============================] - 0s 2ms/step - loss: 3729.6279
Epoch 42/100
30/30 [==============================] - 0s 2ms/step - loss: 3707.3220
Epoch 43/100
30/30 [==============================] - 0s 2ms/step - loss: 3684.3977
Epoch 44/100
30/30 [==============================] - 0s 2ms/step - loss: 3662.9819
Epoch 45/100
30/30 [==============================] - 0s 2ms/step - loss: 3638.6604
Epoch 46/100
30/30 [==============================] - 0s 2ms/step - loss: 3617.3979
Epoch 47/100
30/30 [==============================] - 0s 2ms/step - loss: 3598.9995
Epoch 48/100
30/30 [==============================] - 0s 2ms/step - loss: 3580.4583
Epoch 49/100
30/30 [==============================] - 0s 2ms/step - loss: 3556.3406
Epoch 50/100
30/30 [==============================] - 0s 2ms/step - loss: 3538.8979
Epoch 51/100
30/30 [==============================] - 0s 2ms/step - loss: 3521.2136
Epoch 52/100
30/30 [==============================] - 0s 2ms/step - loss: 3506.3403
```

```
Epoch 53/100
30/30 [==============================] - 0s 3ms/step - loss: 3487.2502
Epoch 54/100
30/30 [==============================] - 0s 3ms/step - loss: 3471.2744
Epoch 55/100
30/30 [==============================] - 0s 3ms/step - loss: 3456.6909
Epoch 56/100
30/30 [==============================] - 0s 3ms/step - loss: 3440.3547
Epoch 57/100
30/30 [==============================] - 0s 3ms/step - loss: 3425.8894
Epoch 58/100
30/30 [==============================] - 0s 2ms/step - loss: 3410.8403
Epoch 59/100
30/30 [==============================] - 0s 2ms/step - loss: 3397.1768
Epoch 60/100
30/30 [==============================] - 0s 2ms/step - loss: 3382.8694
Epoch 61/100
30/30 [==============================] - 0s 2ms/step - loss: 3370.2993
Epoch 62/100
30/30 [==============================] - 0s 3ms/step - loss: 3355.5266
Epoch 63/100
30/30 [==============================] - 0s 3ms/step - loss: 3342.4912
Epoch 64/100
30/30 [==============================] - 0s 2ms/step - loss: 3332.2273
Epoch 65/100
30/30 [==============================] - 0s 2ms/step - loss: 3322.3694
```

```
Epoch 66/100
30/30 [==============================] - 0s 2ms/step - loss: 3309.6792
Epoch 67/100
30/30 [==============================] - 0s 2ms/step - loss: 3298.7219
Epoch 68/100
30/30 [==============================] - 0s 2ms/step - loss: 3286.4268
Epoch 69/100
30/30 [==============================] - 0s 2ms/step - loss: 3273.8982
Epoch 70/100
30/30 [==============================] - 0s 2ms/step - loss: 3263.5498
Epoch 71/100
30/30 [==============================] - 0s 2ms/step - loss: 3252.9829
Epoch 72/100
30/30 [==============================] - 0s 2ms/step - loss: 3243.4307
Epoch 73/100
30/30 [==============================] - 0s 3ms/step - loss: 3235.1936
Epoch 74/100
30/30 [==============================] - 0s 3ms/step - loss: 3231.0186
Epoch 75/100
30/30 [==============================] - 0s 3ms/step - loss: 3215.4075
Epoch 76/100
30/30 [==============================] - 0s 3ms/step - loss: 3205.0139
Epoch 77/100
30/30 [==============================] - 0s 3ms/step - loss: 3198.0327
Epoch 78/100
30/30 [==============================] - 0s 2ms/step - loss: 3188.8215
```

```
Epoch 79/100
30/30 [==============================] - 0s 2ms/step - loss: 3178.7202
Epoch 80/100
30/30 [==============================] - 0s 2ms/step - loss: 3171.6448
Epoch 81/100
30/30 [==============================] - 0s 2ms/step - loss: 3165.1074
Epoch 82/100
30/30 [==============================] - 0s 3ms/step - loss: 3155.5808
Epoch 83/100
30/30 [==============================] - 0s 2ms/step - loss: 3148.1201
Epoch 84/100
30/30 [==============================] - 0s 2ms/step - loss: 3142.3447
Epoch 85/100
30/30 [==============================] - 0s 2ms/step - loss: 3133.1785
Epoch 86/100
30/30 [==============================] - 0s 2ms/step - loss: 3127.1279
Epoch 87/100
30/30 [==============================] - 0s 2ms/step - loss: 3119.1167
Epoch 88/100
30/30 [==============================] - 0s 2ms/step - loss: 3117.7542
Epoch 89/100
30/30 [==============================] - 0s 3ms/step - loss: 3106.5811
Epoch 90/100
30/30 [==============================] - 0s 3ms/step - loss: 3099.8523
Epoch 91/100
30/30 [==============================] - 0s 3ms/step - loss: 3097.7727
Epoch 92/100
30/30 [==============================] - 0s 2ms/step - loss: 3088.9355
Epoch 93/100
30/30 [==============================] - 0s 3ms/step - loss: 3084.4216
```

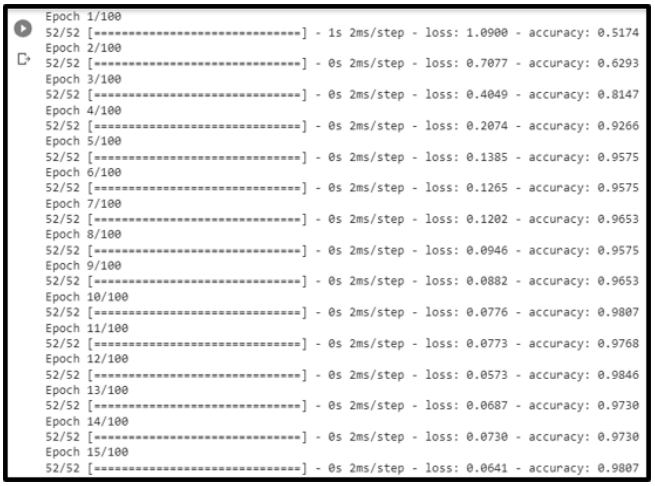
```
Epoch 94/100
30/30 [==============================] - 0s 3ms/step - loss: 3077.5557
Epoch 95/100
30/30 [==============================] - 0s 3ms/step - loss: 3070.2825
Epoch 96/100
30/30 [==============================] - 0s 2ms/step - loss: 3067.0361
Epoch 97/100
30/30 [==============================] - 0s 2ms/step - loss: 3064.9561
Epoch 98/100
30/30 [==============================] - 0s 2ms/step - loss: 3056.0903
Epoch 99/100
30/30 [==============================] - 0s 2ms/step - loss: 3051.7939
Epoch 100/100
30/30 [==============================] - 0s 2ms/step - loss: 3046.2048
<keras.callbacks.History at 0x7f231ea36bf0>
```

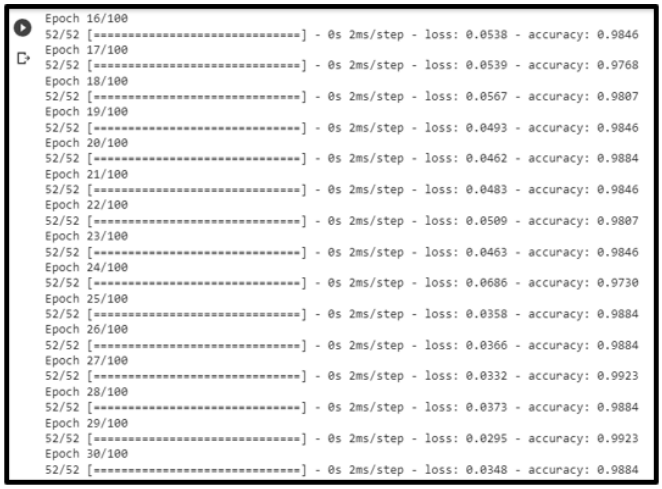
Evaluación de rendimiento con Cross Validation

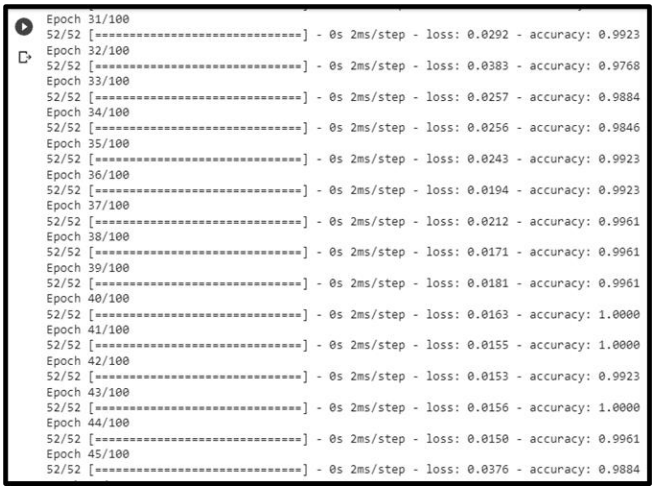
```
4/4 [==============================] - 0s 3ms/step
4/4 [==============================] - 0s 3ms/step
4/4 [==============================] - 0s 3ms/step
4/4 [==============================] - 0s 3ms/step
4/4 [==============================] - 0s 3ms/step
ACC =  0.7708176100628931
```

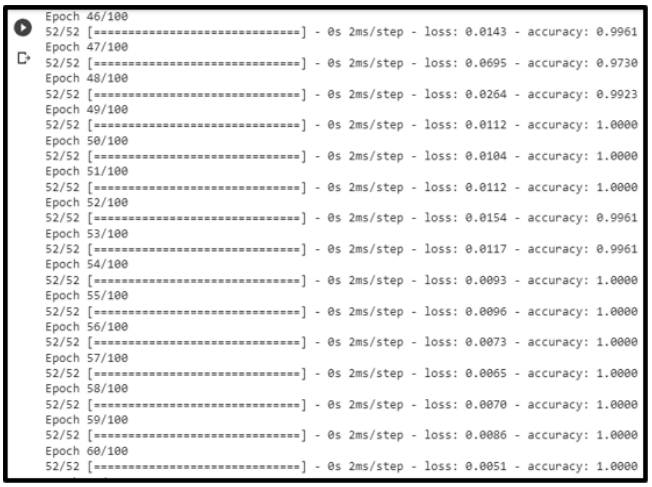
Link a colab:
https://colab.research.google.com/drive/1Dl_wimcmO_v51Ss8fQL6c9Xr0uam3XRY?usp=sharing

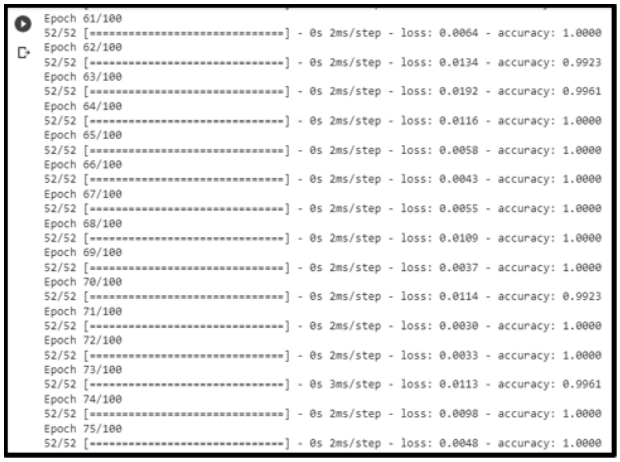
- **2.2**

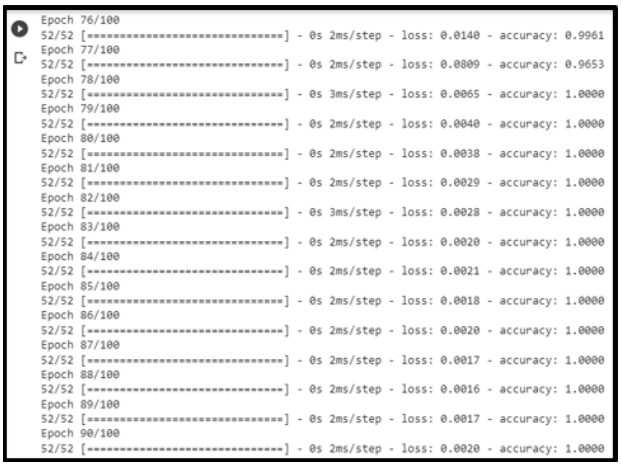












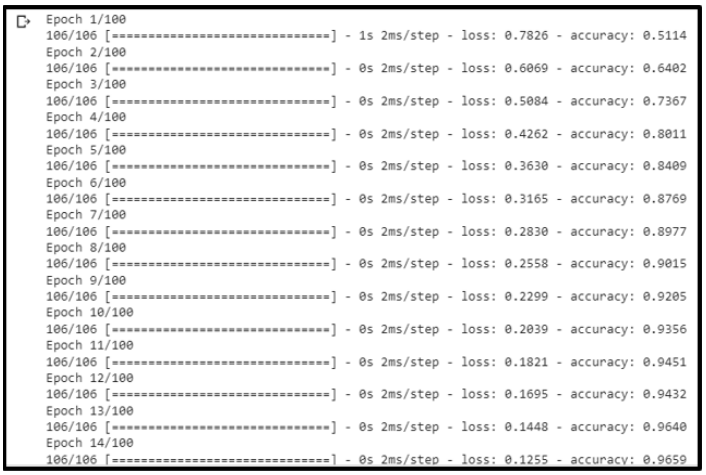
```
Epoch 91/100
52/52 [==============================] - 0s 3ms/step - loss: 0.0016 - accuracy: 1.0000
Epoch 92/100
52/52 [==============================] - 0s 2ms/step - loss: 0.0016 - accuracy: 1.0000
Epoch 93/100
52/52 [==============================] - 0s 2ms/step - loss: 0.0014 - accuracy: 1.0000
Epoch 94/100
52/52 [==============================] - 0s 3ms/step - loss: 0.0013 - accuracy: 1.0000
Epoch 95/100
52/52 [==============================] - 0s 3ms/step - loss: 0.0011 - accuracy: 1.0000
Epoch 96/100
52/52 [==============================] - 0s 2ms/step - loss: 0.0029 - accuracy: 1.0000
Epoch 97/100
52/52 [==============================] - 0s 2ms/step - loss: 0.0011 - accuracy: 1.0000
Epoch 98/100
52/52 [==============================] - 0s 2ms/step - loss: 0.0014 - accuracy: 1.0000
Epoch 99/100
52/52 [==============================] - 0s 2ms/step - loss: 0.0011 - accuracy: 1.0000
Epoch 100/100
52/52 [==============================] - 0s 2ms/step - loss: 0.0011 - accuracy: 1.0000
<keras.callbacks.History at 0x7f3d308aa470>
```

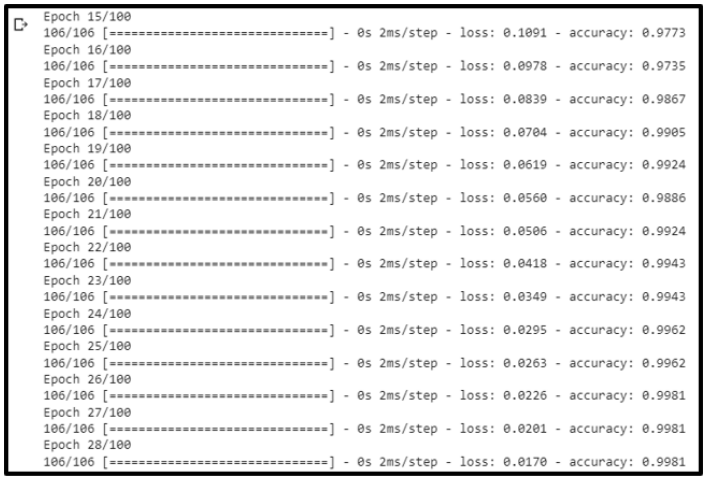
Evaluación de rendimiento con Cross Validation

```
2/2 [==============================] - 0s 4ms/step
2/2 [==============================] - 0s 7ms/step
2/2 [==============================] - 0s 8ms/step
2/2 [==============================] - 0s 7ms/step
WARNING:tensorflow:5 out of the last 9 calls to <function
2/2 [==============================] - 0s 4ms/step
ACC =  0.67579185520362
RECALL =  [0.8 1.  1. ]
```

Link a colab:
https://colab.research.google.com/drive/18u9F0k5z9UzLs20ufYVGzcU9J5ELf_hW#scrollTo=yrvKXq2oNY5Z

- **2.3**





```
[9] Epoch 29/100
    30/30 [==============================] - 0s 3ms/step - loss: 4958.0596
    Epoch 30/100
    30/30 [==============================] - 0s 3ms/step - loss: 4664.7979
    Epoch 31/100
    30/30 [==============================] - 0s 3ms/step - loss: 4473.9468
    Epoch 32/100
    30/30 [==============================] - 0s 2ms/step - loss: 4317.6973
    Epoch 33/100
    30/30 [==============================] - 0s 2ms/step - loss: 4213.2217
    Epoch 34/100
    30/30 [==============================] - 0s 3ms/step - loss: 4133.6343
    Epoch 35/100
    30/30 [==============================] - 0s 3ms/step - loss: 4082.2078
    Epoch 36/100
    30/30 [==============================] - 0s 3ms/step - loss: 4032.3416
    Epoch 37/100
    30/30 [==============================] - 0s 3ms/step - loss: 3996.6780
    Epoch 38/100
    30/30 [==============================] - 0s 3ms/step - loss: 3966.8091
    Epoch 39/100
    30/30 [==============================] - 0s 2ms/step - loss: 3935.7085
    Epoch 40/100
    30/30 [==============================] - 0s 4ms/step - loss: 3907.2139
    Epoch 41/100
    30/30 [==============================] - 0s 3ms/step - loss: 3883.7017
    Epoch 42/100
    30/30 [==============================] - 0s 3ms/step - loss: 3858.1514
    Epoch 43/100
    30/30 [==============================] - 0s 3ms/step - loss: 3835.0774
```

```
[9] Epoch 44/100
    30/30 [==============================] - 0s 3ms/step - loss: 3814.5999
    Epoch 45/100
    30/30 [==============================] - 0s 4ms/step - loss: 3791.2356
    Epoch 46/100
    30/30 [==============================] - 0s 3ms/step - loss: 3771.9424
    Epoch 47/100
    30/30 [==============================] - 0s 3ms/step - loss: 3749.5679
    Epoch 48/100
    30/30 [==============================] - 0s 3ms/step - loss: 3728.9309
    Epoch 49/100
    30/30 [==============================] - 0s 3ms/step - loss: 3709.9995
    Epoch 50/100
    30/30 [==============================] - 0s 4ms/step - loss: 3686.1482
    Epoch 51/100
    30/30 [==============================] - 0s 3ms/step - loss: 3662.3887
    Epoch 52/100
    30/30 [==============================] - 0s 3ms/step - loss: 3640.9287
    Epoch 53/100
    30/30 [==============================] - 0s 4ms/step - loss: 3618.6025
    Epoch 54/100
    30/30 [==============================] - 0s 3ms/step - loss: 3598.1711
    Epoch 55/100
    30/30 [==============================] - 0s 4ms/step - loss: 3576.7175
    Epoch 56/100
    30/30 [==============================] - 0s 3ms/step - loss: 3560.3926
    Epoch 57/100
    30/30 [==============================] - 0s 3ms/step - loss: 3539.4600
    Epoch 58/100
    30/30 [==============================] - 0s 2ms/step - loss: 3519.4089
```

```
Epoch 59/100
30/30 [==============================] - 0s 3ms/step - loss: 3500.7261
Epoch 60/100
30/30 [==============================] - 0s 3ms/step - loss: 3483.8577
Epoch 61/100
30/30 [==============================] - 0s 2ms/step - loss: 3466.8291
Epoch 62/100
30/30 [==============================] - 0s 2ms/step - loss: 3450.8230
Epoch 63/100
30/30 [==============================] - 0s 2ms/step - loss: 3434.4272
Epoch 64/100
30/30 [==============================] - 0s 2ms/step - loss: 3419.3911
Epoch 65/100
30/30 [==============================] - 0s 2ms/step - loss: 3403.5750
Epoch 66/100
30/30 [==============================] - 0s 14ms/step - loss: 3394.1340
Epoch 67/100
30/30 [==============================] - 0s 2ms/step - loss: 3374.1448
Epoch 68/100
30/30 [==============================] - 0s 3ms/step - loss: 3361.1343
Epoch 69/100
30/30 [==============================] - 0s 2ms/step - loss: 3348.2896
Epoch 70/100
30/30 [==============================] - 0s 3ms/step - loss: 3336.0471
Epoch 71/100
30/30 [==============================] - 0s 2ms/step - loss: 3322.8154
Epoch 72/100
30/30 [==============================] - 0s 3ms/step - loss: 3311.3518
Epoch 73/100
30/30 [==============================] - 0s 3ms/step - loss: 3297.5015
```

```
Epoch 74/100
30/30 [==============================] - 0s 2ms/step - loss: 3286.0142
Epoch 75/100
30/30 [==============================] - 0s 4ms/step - loss: 3273.8267
Epoch 76/100
30/30 [==============================] - 0s 3ms/step - loss: 3262.7678
Epoch 77/100
30/30 [==============================] - 0s 3ms/step - loss: 3252.9111
Epoch 78/100
30/30 [==============================] - 0s 3ms/step - loss: 3242.3433
Epoch 79/100
30/30 [==============================] - 0s 4ms/step - loss: 3229.1555
Epoch 80/100
30/30 [==============================] - 0s 4ms/step - loss: 3219.9844
Epoch 81/100
30/30 [==============================] - 0s 3ms/step - loss: 3211.4890
Epoch 82/100
30/30 [==============================] - 0s 2ms/step - loss: 3202.4324
Epoch 83/100
30/30 [==============================] - 0s 2ms/step - loss: 3193.0623
Epoch 84/100
30/30 [==============================] - 0s 4ms/step - loss: 3183.8398
Epoch 85/100
30/30 [==============================] - 0s 3ms/step - loss: 3176.1289
Epoch 86/100
30/30 [==============================] - 0s 2ms/step - loss: 3166.0198
Epoch 87/100
30/30 [==============================] - 0s 3ms/step - loss: 3158.1790
Epoch 88/100
30/30 [==============================] - 0s 3ms/step - loss: 3149.9050
```

```
Epoch 89/100
30/30 [==============================] - 0s 2ms/step - loss: 3141.5430
Epoch 90/100
30/30 [==============================] - 0s 2ms/step - loss: 3135.0129
Epoch 91/100
30/30 [==============================] - 0s 2ms/step - loss: 3128.0996
Epoch 92/100
30/30 [==============================] - 0s 3ms/step - loss: 3121.8960
Epoch 93/100
30/30 [==============================] - 0s 3ms/step - loss: 3112.0410
Epoch 94/100
30/30 [==============================] - 0s 2ms/step - loss: 3105.7148
Epoch 95/100
30/30 [==============================] - 0s 2ms/step - loss: 3101.0239
Epoch 96/100
30/30 [==============================] - 0s 4ms/step - loss: 3091.9585
Epoch 97/100
30/30 [==============================] - 0s 3ms/step - loss: 3086.3069
Epoch 98/100
30/30 [==============================] - 0s 3ms/step - loss: 3083.0288
Epoch 99/100
30/30 [==============================] - 0s 3ms/step - loss: 3074.6631
Epoch 100/100
30/30 [==============================] - 0s 2ms/step - loss: 3070.8464
<keras.callbacks.History at 0x7f4765b16bc0>
```

Evaluación de rendimiento con Cross Validation

```
3/3 [==============================] - 0s 4ms/step
mse =  3105.194119869278
r^2=  0.4787372497671115
3/3 [==============================] - 0s 4ms/step
mse =  3891.809469494988
r^2=  0.3923464526662185
3/3 [==============================] - 0s 3ms/step
mse =  3443.1624462977566
r^2=  0.3886781851221942
3/3 [==============================] - 0s 2ms/step
mse =  3486.1524722996633
r^2=  0.4014738688537143
3/3 [==============================] - 0s 3ms/step
mse =  3062.9767358163035
r^2=  0.44436877793201224
MSE =  3397.859048755598
R^2 =  0.42112090686825016
```

Link a colab:
https://colab.research.google.com/drive/1e6lWYVHfSC6TcbN_L4tNrPkK_C07G60f#scrollTo=l-FqwtTFaU8C

Conclusión

Gracias a esta actividad pudimos observar las diferentes formas de implementar y entrenar una neurona perceptrón con el gradiente estocástico, además de el entrenamiento con sus variantes como lo son gradiente estocástico batch y gradiente estocástico mini batch, mediante un archivo de dataset. Asimismo, pudimos observar los resultados al modelar un perceptrón multicapa con dos clases, cuatro clases así como un modelo de regresión perceptrón multicapa.