

# cancer\_classifier

March 23, 2020

## 1 Clasificación de cancer con una red neuronal

En este notebook se va a desarrollar la implementación de una red neuronal de 3 capas, con 9 entradas, 15 neuronas en la capa oculta y una neurona con función de salida sigmoide en la última capa. El objetivo es determinar, partiendo de un csv, la naturaleza de los tumores en función de sus características. Para el mejor entendimiento del ejercicio, el notebook se separa en dos secciones: - Preparación de los datos. - Instanciación de la red neuronal (desarrollada en NeuralNetwork.py) y uso con los parámetros más óptimos encontrados.

### 1.1 Preparación de los datos

#### 1.1.1 Imports

```
[1]: import numpy as np
import matplotlib.pyplot as plt
import random
from sklearn.metrics import mean_squared_error
import pandas as pd
from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import confusion_matrix
import itertools
import seaborn as sns
from NeuralNetwork import *
```

#### 1.1.2 Load and format data

El dataset viene con la salida definida como 2 ó 4, la cambiamos a 0 ó 1 para poder trabajar. También se eliminan aquellas filas con algún valor nulo. Las entradas de la red neuronal corresponderán a: - Clump Thickness - Uniformity of Cell Size - Uniformity of Cell Shape - Marginal Adhesion - Single Epithelial Cell Size - Bare Nuclei - Bland Chromatin - Normal Nucleoli - Mitoses

```
[2]: #load and format data
df = pd.read_csv('wisconsin-cancer-dataset.csv', header=None)
df.head(5)
df.iloc[:,10].replace(2, 0, inplace=True)
df.iloc[:,10].replace(4, 1, inplace=True)
df = df[~df[6].isin(['?'])]
df = df.astype(float)
```

```
df.head(5)
```

```
[2]:
```

	0	1	2	3	4	5	6	7	8	9	10
0	1000025.0	5.0	1.0	1.0	1.0	2.0	1.0	3.0	1.0	1.0	0.0
1	1002945.0	5.0	4.0	4.0	5.0	7.0	10.0	3.0	2.0	1.0	0.0
2	1015425.0	3.0	1.0	1.0	1.0	2.0	2.0	3.0	1.0	1.0	0.0
3	1016277.0	6.0	8.0	8.0	1.0	3.0	4.0	3.0	7.0	1.0	0.0
4	1017023.0	4.0	1.0	1.0	3.0	2.0	1.0	3.0	1.0	1.0	0.0

### 1.1.3 Feature Normalization

Se normaliza las características para acotarlas todas en un intervalo entre 0 y 1, con el objetivo de que ninguna de ellas condicione en exceso el ejercicio o pase desapercibida. Se muestran los valores de las características. Para el desarrollo del ejercicio solo nos interesan las características del 1 al 9.

```
[3]: names = df.columns[0:10]
scaler = MinMaxScaler()
scaled_df = scaler.fit_transform(df.iloc[:,0:10])
scaled_df = pd.DataFrame(scaled_df, columns=names)
scaled_df[10]= df[10]
#scaled_df.iloc[0:13,1:11].plot.bar();
#scaled_df.iloc[0:13,1:11].plot.hist(alpha=0.5)
```

### 1.1.4 Creation of train and validation sets

Para la posterior evaluación de la clasificación, creamos un set de entrenamiento y otro menor de validación.

```
[4]: x=scaled_df.iloc[0:500,1:10].values.transpose()
y=df.iloc[0:500,10:].values.transpose()
xval=scaled_df.iloc[501:683,1:10].values.transpose()
yval=df.iloc[501:683,10:].values.transpose()
```

## 1.2 Network Development

### 1.2.1 Declaring nn

Declaramos la red neuronal con los valores de entrenamiento y un learning rate de 0.02. La red funciona con una arquitectura [9 - 15 - 1], la cual utiliza funciones de salida lineales en la capa intermedia y una sigmoideal en la de salida. Utiliza como función de error, en lugar del clásico MSE, el Cross-Entropy. El algoritmo de aprendizaje utilizado es el descenso por gradiente, el cual implementa el algoritmo de backpropagation.

```
[5]: nn = NeuralNetwork(x,y,0.01,0)
nn.gradient_descent(50000)
```

Cost after iteration 0: 0.257234

Cost after iteration 100: 0.214475

Cost after iteration 200: 0.182112  
Cost after iteration 300: 0.157673  
Cost after iteration 400: 0.138460  
Cost after iteration 500: 0.122704  
Cost after iteration 600: 0.109399  
Cost after iteration 700: 0.097997  
Cost after iteration 800: 0.088188  
Cost after iteration 900: 0.079769  
Cost after iteration 1000: 0.072575  
Cost after iteration 1100: 0.066458  
Cost after iteration 1200: 0.061276  
Cost after iteration 1300: 0.056900  
Cost after iteration 1400: 0.053212  
Cost after iteration 1500: 0.050106  
Cost after iteration 1600: 0.047491  
Cost after iteration 1700: 0.045289  
Cost after iteration 1800: 0.043431  
Cost after iteration 1900: 0.041862  
Cost after iteration 2000: 0.040532  
Cost after iteration 2100: 0.039400  
Cost after iteration 2200: 0.038433  
Cost after iteration 2300: 0.037603  
Cost after iteration 2400: 0.036886  
Cost after iteration 2500: 0.036263  
Cost after iteration 2600: 0.035718  
Cost after iteration 2700: 0.035238  
Cost after iteration 2800: 0.034811  
Cost after iteration 2900: 0.034431  
Cost after iteration 3000: 0.034088  
Cost after iteration 3100: 0.033777  
Cost after iteration 3200: 0.033494  
Cost after iteration 3300: 0.033234  
Cost after iteration 3400: 0.032993  
Cost after iteration 3500: 0.032771  
Cost after iteration 3600: 0.032563  
Cost after iteration 3700: 0.032368  
Cost after iteration 3800: 0.032186  
Cost after iteration 3900: 0.032013  
Cost after iteration 4000: 0.031850  
Cost after iteration 4100: 0.031696  
Cost after iteration 4200: 0.031549  
Cost after iteration 4300: 0.031409  
Cost after iteration 4400: 0.031276  
Cost after iteration 4500: 0.031148  
Cost after iteration 4600: 0.031026  
Cost after iteration 4700: 0.030910  
Cost after iteration 4800: 0.030798  
Cost after iteration 4900: 0.030692

Cost after iteration 5000: 0.030589  
Cost after iteration 5100: 0.030491  
Cost after iteration 5200: 0.030396  
Cost after iteration 5300: 0.030306  
Cost after iteration 5400: 0.030219  
Cost after iteration 5500: 0.030135  
Cost after iteration 5600: 0.030055  
Cost after iteration 5700: 0.029978  
Cost after iteration 5800: 0.029903  
Cost after iteration 5900: 0.029832  
Cost after iteration 6000: 0.029763  
Cost after iteration 6100: 0.029697  
Cost after iteration 6200: 0.029634  
Cost after iteration 6300: 0.029573  
Cost after iteration 6400: 0.029514  
Cost after iteration 6500: 0.029457  
Cost after iteration 6600: 0.029403  
Cost after iteration 6700: 0.029350  
Cost after iteration 6800: 0.029299  
Cost after iteration 6900: 0.029251  
Cost after iteration 7000: 0.029204  
Cost after iteration 7100: 0.029158  
Cost after iteration 7200: 0.029115  
Cost after iteration 7300: 0.029073  
Cost after iteration 7400: 0.029032  
Cost after iteration 7500: 0.028993  
Cost after iteration 7600: 0.028955  
Cost after iteration 7700: 0.028918  
Cost after iteration 7800: 0.028883  
Cost after iteration 7900: 0.028849  
Cost after iteration 8000: 0.028816  
Cost after iteration 8100: 0.028784  
Cost after iteration 8200: 0.028753  
Cost after iteration 8300: 0.028723  
Cost after iteration 8400: 0.028694  
Cost after iteration 8500: 0.028666  
Cost after iteration 8600: 0.028639  
Cost after iteration 8700: 0.028612  
Cost after iteration 8800: 0.028587  
Cost after iteration 8900: 0.028562  
Cost after iteration 9000: 0.028537  
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Cost after iteration 9500: 0.028425  
Cost after iteration 9600: 0.028405  
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Cost after iteration 9800: 0.028364  
Cost after iteration 9900: 0.028345  
Cost after iteration 10000: 0.028326  
Cost after iteration 10100: 0.028307  
Cost after iteration 10200: 0.028289  
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Cost after iteration 11200: 0.028116  
Cost after iteration 11300: 0.028100  
Cost after iteration 11400: 0.028083  
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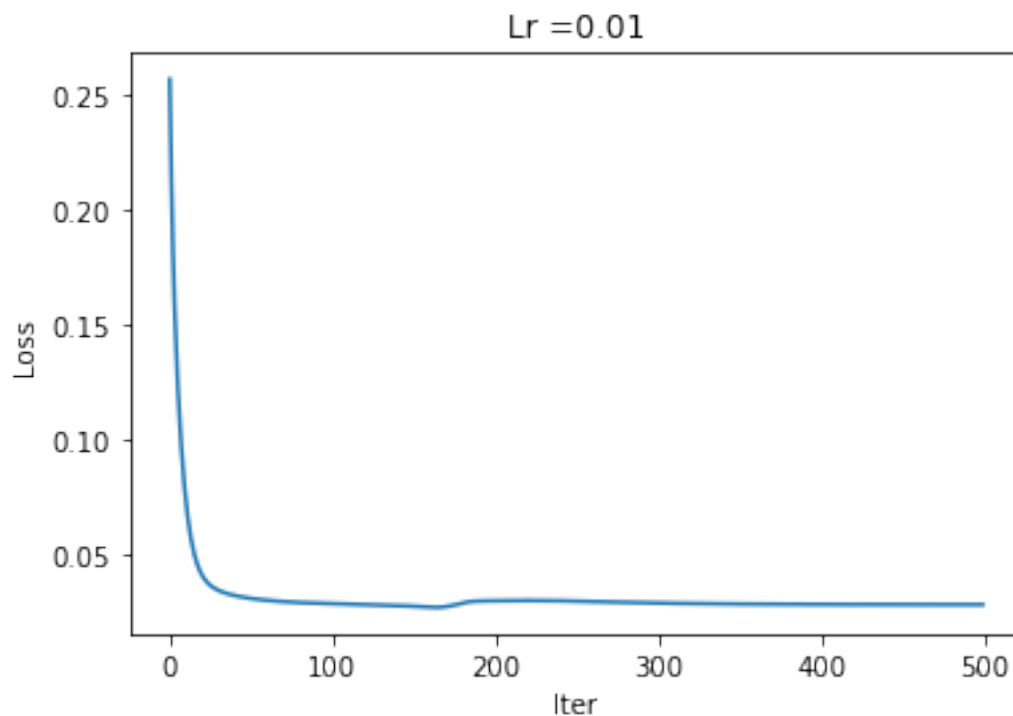
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```



### 1.2.2 Predict and comparing training accuracy vs validation accuracy

Comparamos el acierto desempeñado por nuestra red neuronal, tanto en el test de entrenamiento como en el de validación. Se prefiere un mejor resultado en el de validación que en el de entrenamiento, ya que esto es signo de que, a priori, no existe ningún tipo de problema de vias o de

variance.

```
[6]: pred_train = nn.predict(x, y)
     pred_test = nn.predict(xval, yval)
```

Acc: 0.9240000000000003

Acc: 0.9835164835164836

### 1.2.3 Function to plot the performance of the nn (skewed classes)

```
[7]: def plotCf(a,b,t):
     cf = confusion_matrix(a,b)
     plt.imshow(cf, cmap=plt.cm.Blues, interpolation='nearest')
     plt.colorbar()
     plt.title(t)
     plt.xlabel('0          Predicted          1')
     plt.ylabel('1          Actual            0')
     tick_marks = np.arange(len(set(a))) # length of classes
     class_labels = ['0', '1']
     plt.xticks(np.ndarray([0,1]))
     plt.yticks(np.ndarray([0,1]))
     for i,j in itertools.product(range(cf.shape[0]), range(cf.shape[1])):
         plt.
         ↪text(j,i,format(cf[i,j], 'd'), horizontalalignment='center', color='white' if
         ↪cf[i,j] > (cf.max()*0.7) else 'black')
     plt.show();
```

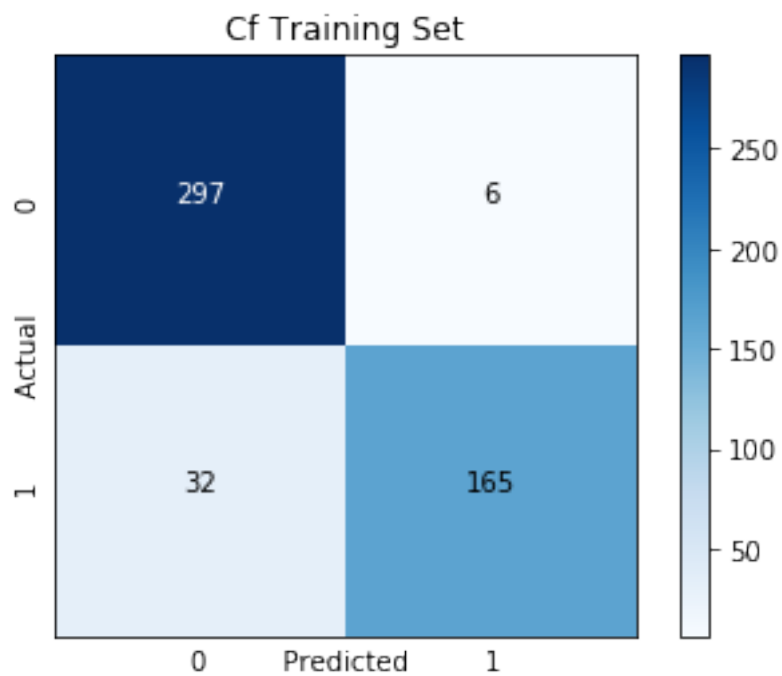
### 1.2.4 Check how well it predict!

Dado los buenos resultados obtenidos, se procede a hacer la predicción, tanto con los datos de entrenamiento como con los de validación.

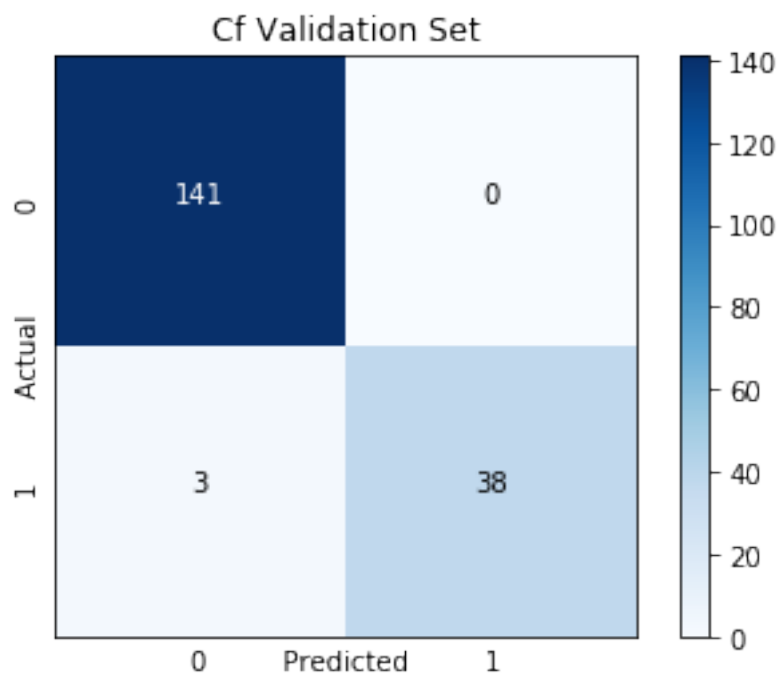
```
[8]: nn.threshold=0.90#0.85
     nn.X,nn.Y=x, y
     target=np.around(np.squeeze(y), decimals=0).astype(np.int)
     predicted=np.around(np.squeeze(nn.predict(x,y)), decimals=0).astype(np.int)
     plotCf(target,predicted,'Cf Training Set')

     nn.X,nn.Y=xval, yval
     target=np.around(np.squeeze(yval), decimals=0).astype(np.int)
     predicted=np.around(np.squeeze(nn.predict(xval,yval)), decimals=0).astype(np.
     ↪int)
     plotCf(target,predicted,'Cf Validation Set')
```

Acc: 0.9240000000000003



Acc: 0.9835164835164836



### 1.3 Regularized

```
[9]: nnr = NeuralNetwork(x,y,0.01,0.95)
     nnr.gradient_descent_regu(50000)
```

```
Cost after iteration 0: 0.257234
Cost after iteration 100: 0.214368
Cost after iteration 200: 0.181792
Cost after iteration 300: 0.157165
Cost after iteration 400: 0.137801
Cost after iteration 500: 0.121914
Cost after iteration 600: 0.108492
Cost after iteration 700: 0.096992
Cost after iteration 800: 0.087109
Cost after iteration 900: 0.078645
Cost after iteration 1000: 0.071435
Cost after iteration 1100: 0.065327
Cost after iteration 1200: 0.060175
Cost after iteration 1300: 0.055846
Cost after iteration 1400: 0.052216
Cost after iteration 1500: 0.049177
Cost after iteration 1600: 0.046635
Cost after iteration 1700: 0.044506
Cost after iteration 1800: 0.042722
Cost after iteration 1900: 0.041223
Cost after iteration 2000: 0.039959
Cost after iteration 2100: 0.038890
Cost after iteration 2200: 0.037980
Cost after iteration 2300: 0.037202
Cost after iteration 2400: 0.036533
Cost after iteration 2500: 0.035952
Cost after iteration 2600: 0.035445
Cost after iteration 2700: 0.034998
Cost after iteration 2800: 0.034601
Cost after iteration 2900: 0.034247
Cost after iteration 3000: 0.033927
Cost after iteration 3100: 0.033636
Cost after iteration 3200: 0.033370
Cost after iteration 3300: 0.033126
Cost after iteration 3400: 0.032899
Cost after iteration 3500: 0.032688
Cost after iteration 3600: 0.032490
Cost after iteration 3700: 0.032304
Cost after iteration 3800: 0.032129
Cost after iteration 3900: 0.031963
Cost after iteration 4000: 0.031805
Cost after iteration 4100: 0.031655
Cost after iteration 4200: 0.031512
```



Cost after iteration 4300: 0.031375  
Cost after iteration 4400: 0.031244  
Cost after iteration 4500: 0.031119  
Cost after iteration 4600: 0.030999  
Cost after iteration 4700: 0.030884  
Cost after iteration 4800: 0.030773  
Cost after iteration 4900: 0.030666  
Cost after iteration 5000: 0.030564  
Cost after iteration 5100: 0.030466  
Cost after iteration 5200: 0.030371  
Cost after iteration 5300: 0.030280  
Cost after iteration 5400: 0.030193  
Cost after iteration 5500: 0.030108  
Cost after iteration 5600: 0.030027  
Cost after iteration 5700: 0.029949  
Cost after iteration 5800: 0.029873  
Cost after iteration 5900: 0.029801  
Cost after iteration 6000: 0.029731  
Cost after iteration 6100: 0.029663  
Cost after iteration 6200: 0.029598  
Cost after iteration 6300: 0.029535  
Cost after iteration 6400: 0.029474  
Cost after iteration 6500: 0.029415  
Cost after iteration 6600: 0.029359  
Cost after iteration 6700: 0.029304  
Cost after iteration 6800: 0.029250  
Cost after iteration 6900: 0.029199  
Cost after iteration 7000: 0.029149  
Cost after iteration 7100: 0.029101  
Cost after iteration 7200: 0.029054  
Cost after iteration 7300: 0.029008  
Cost after iteration 7400: 0.028964  
Cost after iteration 7500: 0.028920  
Cost after iteration 7600: 0.028878  
Cost after iteration 7700: 0.028837  
Cost after iteration 7800: 0.028797  
Cost after iteration 7900: 0.028758  
Cost after iteration 8000: 0.028719  
Cost after iteration 8100: 0.028681  
Cost after iteration 8200: 0.028644  
Cost after iteration 8300: 0.028608  
Cost after iteration 8400: 0.028571  
Cost after iteration 8500: 0.028536  
Cost after iteration 8600: 0.028500  
Cost after iteration 8700: 0.028465  
Cost after iteration 8800: 0.028430  
Cost after iteration 8900: 0.028395  
Cost after iteration 9000: 0.028360

Cost after iteration 9100: 0.028325  
Cost after iteration 9200: 0.028290  
Cost after iteration 9300: 0.028255  
Cost after iteration 9400: 0.028219  
Cost after iteration 9500: 0.028183  
Cost after iteration 9600: 0.028147  
Cost after iteration 9700: 0.028109  
Cost after iteration 9800: 0.028071  
Cost after iteration 9900: 0.028032  
Cost after iteration 10000: 0.027993  
Cost after iteration 10100: 0.027952  
Cost after iteration 10200: 0.027910  
Cost after iteration 10300: 0.027866  
Cost after iteration 10400: 0.027821  
Cost after iteration 10500: 0.027775  
Cost after iteration 10600: 0.027727  
Cost after iteration 10700: 0.027677  
Cost after iteration 10800: 0.027625  
Cost after iteration 10900: 0.027571  
Cost after iteration 11000: 0.027516  
Cost after iteration 11100: 0.027458  
Cost after iteration 11200: 0.027398  
Cost after iteration 11300: 0.027336  
Cost after iteration 11400: 0.027273  
Cost after iteration 11500: 0.027208  
Cost after iteration 11600: 0.027142  
Cost after iteration 11700: 0.027076  
Cost after iteration 11800: 0.027010  
Cost after iteration 11900: 0.026946  
Cost after iteration 12000: 0.026886  
Cost after iteration 12100: 0.026830  
Cost after iteration 12200: 0.026783  
Cost after iteration 12300: 0.026747  
Cost after iteration 12400: 0.026724  
Cost after iteration 12500: 0.026720  
Cost after iteration 12600: 0.026738  
Cost after iteration 12700: 0.026781  
Cost after iteration 12800: 0.026851  
Cost after iteration 12900: 0.026948  
Cost after iteration 13000: 0.027068  
Cost after iteration 13100: 0.027202  
Cost after iteration 13200: 0.027339  
Cost after iteration 13300: 0.027465  
Cost after iteration 13400: 0.027571  
Cost after iteration 13500: 0.027663  
Cost after iteration 13600: 0.027760  
Cost after iteration 13700: 0.027891  
Cost after iteration 13800: 0.028074

Cost after iteration 13900: 0.028300  
Cost after iteration 14000: 0.028539  
Cost after iteration 14100: 0.028756  
Cost after iteration 14200: 0.028930  
Cost after iteration 14300: 0.029057  
Cost after iteration 14400: 0.029143  
Cost after iteration 14500: 0.029199  
Cost after iteration 14600: 0.029234  
Cost after iteration 14700: 0.029253  
Cost after iteration 14800: 0.029264  
Cost after iteration 14900: 0.029269  
Cost after iteration 15000: 0.029271  
Cost after iteration 15100: 0.029270  
Cost after iteration 15200: 0.029268  
Cost after iteration 15300: 0.029265  
Cost after iteration 15400: 0.029261  
Cost after iteration 15500: 0.029257  
Cost after iteration 15600: 0.029253  
Cost after iteration 15700: 0.029248  
Cost after iteration 15800: 0.029243  
Cost after iteration 15900: 0.029238  
Cost after iteration 16000: 0.029232  
Cost after iteration 16100: 0.029226  
Cost after iteration 16200: 0.029220  
Cost after iteration 16300: 0.029213  
Cost after iteration 16400: 0.029206  
Cost after iteration 16500: 0.029199  
Cost after iteration 16600: 0.029191  
Cost after iteration 16700: 0.029182  
Cost after iteration 16800: 0.029173  
Cost after iteration 16900: 0.029164  
Cost after iteration 17000: 0.029154  
Cost after iteration 17100: 0.029144  
Cost after iteration 17200: 0.029133  
Cost after iteration 17300: 0.029121  
Cost after iteration 17400: 0.029110  
Cost after iteration 17500: 0.029097  
Cost after iteration 17600: 0.029085  
Cost after iteration 17700: 0.029071  
Cost after iteration 17800: 0.029058  
Cost after iteration 17900: 0.029044  
Cost after iteration 18000: 0.029029  
Cost after iteration 18100: 0.029014  
Cost after iteration 18200: 0.028999  
Cost after iteration 18300: 0.028983  
Cost after iteration 18400: 0.028967  
Cost after iteration 18500: 0.028951  
Cost after iteration 18600: 0.028935

Cost after iteration 18700: 0.028918  
Cost after iteration 18800: 0.028901  
Cost after iteration 18900: 0.028883  
Cost after iteration 19000: 0.028866  
Cost after iteration 19100: 0.028848  
Cost after iteration 19200: 0.028830  
Cost after iteration 19300: 0.028812  
Cost after iteration 19400: 0.028794  
Cost after iteration 19500: 0.028776  
Cost after iteration 19600: 0.028757  
Cost after iteration 19700: 0.028739  
Cost after iteration 19800: 0.028721  
Cost after iteration 19900: 0.028702  
Cost after iteration 20000: 0.028684  
Cost after iteration 20100: 0.028665  
Cost after iteration 20200: 0.028647  
Cost after iteration 20300: 0.028629  
Cost after iteration 20400: 0.028611  
Cost after iteration 20500: 0.028593  
Cost after iteration 20600: 0.028575  
Cost after iteration 20700: 0.028557  
Cost after iteration 20800: 0.028539  
Cost after iteration 20900: 0.028522  
Cost after iteration 21000: 0.028504  
Cost after iteration 21100: 0.028487  
Cost after iteration 21200: 0.028470  
Cost after iteration 21300: 0.028453  
Cost after iteration 21400: 0.028437  
Cost after iteration 21500: 0.028421  
Cost after iteration 21600: 0.028405  
Cost after iteration 21700: 0.028389  
Cost after iteration 21800: 0.028373  
Cost after iteration 21900: 0.028358  
Cost after iteration 22000: 0.028343  
Cost after iteration 22100: 0.028329  
Cost after iteration 22200: 0.028314  
Cost after iteration 22300: 0.028300  
Cost after iteration 22400: 0.028286  
Cost after iteration 22500: 0.028273  
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Cost after iteration 22900: 0.028222  
Cost after iteration 23000: 0.028210  
Cost after iteration 23100: 0.028198  
Cost after iteration 23200: 0.028187  
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Cost after iteration 23500: 0.028155  
Cost after iteration 23600: 0.028144  
Cost after iteration 23700: 0.028135  
Cost after iteration 23800: 0.028125  
Cost after iteration 23900: 0.028116  
Cost after iteration 24000: 0.028107  
Cost after iteration 24100: 0.028098  
Cost after iteration 24200: 0.028090  
Cost after iteration 24300: 0.028082  
Cost after iteration 24400: 0.028074  
Cost after iteration 24500: 0.028066  
Cost after iteration 24600: 0.028059  
Cost after iteration 24700: 0.028052  
Cost after iteration 24800: 0.028045  
Cost after iteration 24900: 0.028039  
Cost after iteration 25000: 0.028033  
Cost after iteration 25100: 0.028027  
Cost after iteration 25200: 0.028021  
Cost after iteration 25300: 0.028016  
Cost after iteration 25400: 0.028011  
Cost after iteration 25500: 0.028006  
Cost after iteration 25600: 0.028001  
Cost after iteration 25700: 0.027997  
Cost after iteration 25800: 0.027992  
Cost after iteration 25900: 0.027988  
Cost after iteration 26000: 0.027985  
Cost after iteration 26100: 0.027981  
Cost after iteration 26200: 0.027978  
Cost after iteration 26300: 0.027974  
Cost after iteration 26400: 0.027971  
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Cost after iteration 26600: 0.027966  
Cost after iteration 26700: 0.027964  
Cost after iteration 26800: 0.027962  
Cost after iteration 26900: 0.027960  
Cost after iteration 27000: 0.027958  
Cost after iteration 27100: 0.027956  
Cost after iteration 27200: 0.027955  
Cost after iteration 27300: 0.027953  
Cost after iteration 27400: 0.027952  
Cost after iteration 27500: 0.027951  
Cost after iteration 27600: 0.027951  
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Cost after iteration 28300: 0.027949  
Cost after iteration 28400: 0.027949  
Cost after iteration 28500: 0.027950  
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Cost after iteration 29300: 0.027958  
Cost after iteration 29400: 0.027959  
Cost after iteration 29500: 0.027961  
Cost after iteration 29600: 0.027963  
Cost after iteration 29700: 0.027964  
Cost after iteration 29800: 0.027966  
Cost after iteration 29900: 0.027968  
Cost after iteration 30000: 0.027970  
Cost after iteration 30100: 0.027972  
Cost after iteration 30200: 0.027975  
Cost after iteration 30300: 0.027977  
Cost after iteration 30400: 0.027979  
Cost after iteration 30500: 0.027982  
Cost after iteration 30600: 0.027984  
Cost after iteration 30700: 0.027987  
Cost after iteration 30800: 0.027990  
Cost after iteration 30900: 0.027992  
Cost after iteration 31000: 0.027995  
Cost after iteration 31100: 0.027998  
Cost after iteration 31200: 0.028001  
Cost after iteration 31300: 0.028004  
Cost after iteration 31400: 0.028007  
Cost after iteration 31500: 0.028010  
Cost after iteration 31600: 0.028013  
Cost after iteration 31700: 0.028017  
Cost after iteration 31800: 0.028020  
Cost after iteration 31900: 0.028023  
Cost after iteration 32000: 0.028027  
Cost after iteration 32100: 0.028030  
Cost after iteration 32200: 0.028034  
Cost after iteration 32300: 0.028037  
Cost after iteration 32400: 0.028041  
Cost after iteration 32500: 0.028045  
Cost after iteration 32600: 0.028048  
Cost after iteration 32700: 0.028052  
Cost after iteration 32800: 0.028056  
Cost after iteration 32900: 0.028060  
Cost after iteration 33000: 0.028064

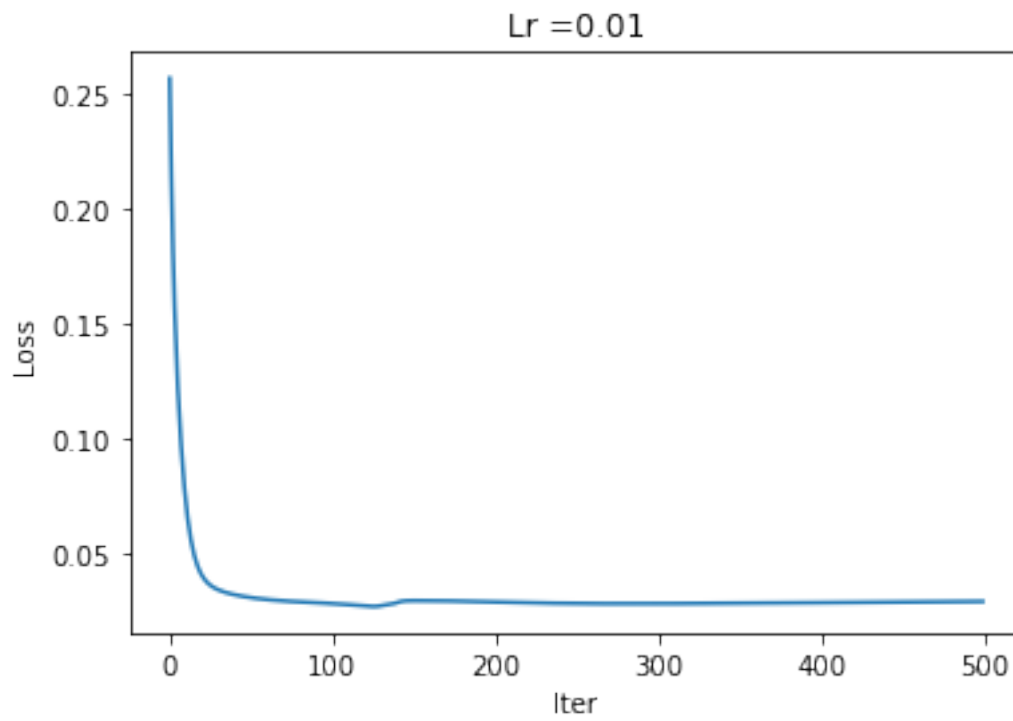
Cost after iteration 33100: 0.028067  
Cost after iteration 33200: 0.028071  
Cost after iteration 33300: 0.028075  
Cost after iteration 33400: 0.028079  
Cost after iteration 33500: 0.028083  
Cost after iteration 33600: 0.028088  
Cost after iteration 33700: 0.028092  
Cost after iteration 33800: 0.028096  
Cost after iteration 33900: 0.028100  
Cost after iteration 34000: 0.028104  
Cost after iteration 34100: 0.028108  
Cost after iteration 34200: 0.028113  
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Cost after iteration 34400: 0.028121  
Cost after iteration 34500: 0.028126  
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Cost after iteration 34900: 0.028143  
Cost after iteration 35000: 0.028148  
Cost after iteration 35100: 0.028152  
Cost after iteration 35200: 0.028157  
Cost after iteration 35300: 0.028161  
Cost after iteration 35400: 0.028166  
Cost after iteration 35500: 0.028170  
Cost after iteration 35600: 0.028175  
Cost after iteration 35700: 0.028180  
Cost after iteration 35800: 0.028184  
Cost after iteration 35900: 0.028189  
Cost after iteration 36000: 0.028193  
Cost after iteration 36100: 0.028198  
Cost after iteration 36200: 0.028203  
Cost after iteration 36300: 0.028208  
Cost after iteration 36400: 0.028212  
Cost after iteration 36500: 0.028217  
Cost after iteration 36600: 0.028222  
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Cost after iteration 36800: 0.028231  
Cost after iteration 36900: 0.028236  
Cost after iteration 37000: 0.028241  
Cost after iteration 37100: 0.028246  
Cost after iteration 37200: 0.028250  
Cost after iteration 37300: 0.028255  
Cost after iteration 37400: 0.028260  
Cost after iteration 37500: 0.028265  
Cost after iteration 37600: 0.028270  
Cost after iteration 37700: 0.028275  
Cost after iteration 37800: 0.028280

Cost after iteration 37900: 0.028285  
Cost after iteration 38000: 0.028289  
Cost after iteration 38100: 0.028294  
Cost after iteration 38200: 0.028299  
Cost after iteration 38300: 0.028304  
Cost after iteration 38400: 0.028309  
Cost after iteration 38500: 0.028314  
Cost after iteration 38600: 0.028319  
Cost after iteration 38700: 0.028324  
Cost after iteration 38800: 0.028329  
Cost after iteration 38900: 0.028334  
Cost after iteration 39000: 0.028339  
Cost after iteration 39100: 0.028344  
Cost after iteration 39200: 0.028349  
Cost after iteration 39300: 0.028354  
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Cost after iteration 39500: 0.028364  
Cost after iteration 39600: 0.028369  
Cost after iteration 39700: 0.028374  
Cost after iteration 39800: 0.028379  
Cost after iteration 39900: 0.028384  
Cost after iteration 40000: 0.028389  
Cost after iteration 40100: 0.028394  
Cost after iteration 40200: 0.028399  
Cost after iteration 40300: 0.028404  
Cost after iteration 40400: 0.028410  
Cost after iteration 40500: 0.028415  
Cost after iteration 40600: 0.028420  
Cost after iteration 40700: 0.028425  
Cost after iteration 40800: 0.028430  
Cost after iteration 40900: 0.028435  
Cost after iteration 41000: 0.028440  
Cost after iteration 41100: 0.028445  
Cost after iteration 41200: 0.028450  
Cost after iteration 41300: 0.028456  
Cost after iteration 41400: 0.028461  
Cost after iteration 41500: 0.028466  
Cost after iteration 41600: 0.028471  
Cost after iteration 41700: 0.028476  
Cost after iteration 41800: 0.028481  
Cost after iteration 41900: 0.028487  
Cost after iteration 42000: 0.028492  
Cost after iteration 42100: 0.028497  
Cost after iteration 42200: 0.028502  
Cost after iteration 42300: 0.028507  
Cost after iteration 42400: 0.028512  
Cost after iteration 42500: 0.028518  
Cost after iteration 42600: 0.028523



Cost after iteration 42700: 0.028528  
Cost after iteration 42800: 0.028533  
Cost after iteration 42900: 0.028539  
Cost after iteration 43000: 0.028544  
Cost after iteration 43100: 0.028549  
Cost after iteration 43200: 0.028554  
Cost after iteration 43300: 0.028559  
Cost after iteration 43400: 0.028565  
Cost after iteration 43500: 0.028570  
Cost after iteration 43600: 0.028575  
Cost after iteration 43700: 0.028580  
Cost after iteration 43800: 0.028586  
Cost after iteration 43900: 0.028591  
Cost after iteration 44000: 0.028596  
Cost after iteration 44100: 0.028602  
Cost after iteration 44200: 0.028607  
Cost after iteration 44300: 0.028612  
Cost after iteration 44400: 0.028617  
Cost after iteration 44500: 0.028623  
Cost after iteration 44600: 0.028628  
Cost after iteration 44700: 0.028633  
Cost after iteration 44800: 0.028639  
Cost after iteration 44900: 0.028644  
Cost after iteration 45000: 0.028649  
Cost after iteration 45100: 0.028655  
Cost after iteration 45200: 0.028660  
Cost after iteration 45300: 0.028665  
Cost after iteration 45400: 0.028671  
Cost after iteration 45500: 0.028676  
Cost after iteration 45600: 0.028681  
Cost after iteration 45700: 0.028687  
Cost after iteration 45800: 0.028692  
Cost after iteration 45900: 0.028697  
Cost after iteration 46000: 0.028703  
Cost after iteration 46100: 0.028708  
Cost after iteration 46200: 0.028714  
Cost after iteration 46300: 0.028719  
Cost after iteration 46400: 0.028724  
Cost after iteration 46500: 0.028730  
Cost after iteration 46600: 0.028735  
Cost after iteration 46700: 0.028741  
Cost after iteration 46800: 0.028746  
Cost after iteration 46900: 0.028751  
Cost after iteration 47000: 0.028757  
Cost after iteration 47100: 0.028762  
Cost after iteration 47200: 0.028768  
Cost after iteration 47300: 0.028773  
Cost after iteration 47400: 0.028779

Cost after iteration 47500: 0.028784  
Cost after iteration 47600: 0.028789  
Cost after iteration 47700: 0.028795  
Cost after iteration 47800: 0.028800  
Cost after iteration 47900: 0.028806  
Cost after iteration 48000: 0.028811  
Cost after iteration 48100: 0.028817  
Cost after iteration 48200: 0.028822  
Cost after iteration 48300: 0.028828  
Cost after iteration 48400: 0.028833  
Cost after iteration 48500: 0.028839  
Cost after iteration 48600: 0.028844  
Cost after iteration 48700: 0.028850  
Cost after iteration 48800: 0.028855  
Cost after iteration 48900: 0.028861  
Cost after iteration 49000: 0.028866  
Cost after iteration 49100: 0.028872  
Cost after iteration 49200: 0.028877  
Cost after iteration 49300: 0.028883  
Cost after iteration 49400: 0.028888  
Cost after iteration 49500: 0.028894  
Cost after iteration 49600: 0.028899  
Cost after iteration 49700: 0.028905  
Cost after iteration 49800: 0.028910  
Cost after iteration 49900: 0.028916



```
[10]: pred_train = nnr.predict(x, y)
      pred_test = nnr.predict(xval, yval)
```

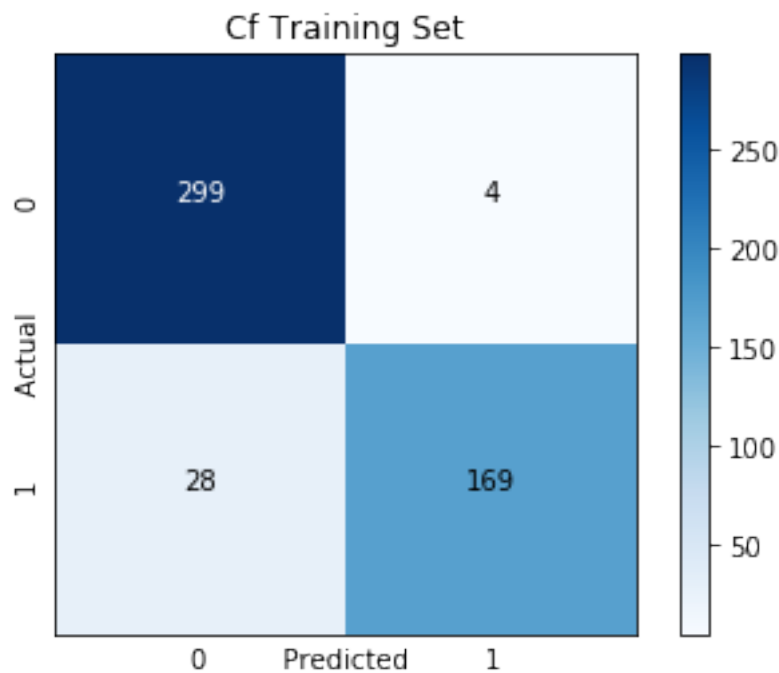
Acc: 0.9360000000000003

Acc: 1.0

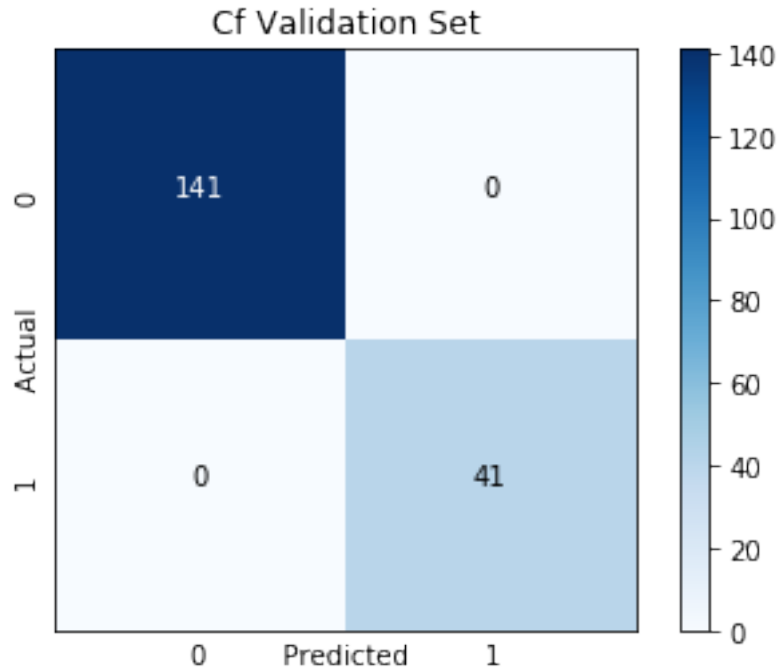
```
[11]: nnr.threshold=0.90#0.85
      nnr.X,nnr.Y=x, y
      target=np.around(np.squeeze(y), decimals=0).astype(np.int)
      predicted=np.around(np.squeeze(nnr.predict(x,y)), decimals=0).astype(np.int)
      plotCf(target,predicted,'Cf Training Set')

      nnr.X,nnr.Y=xval, yval
      target=np.around(np.squeeze(yval), decimals=0).astype(np.int)
      predicted=np.around(np.squeeze(nnr.predict(xval,yval)), decimals=0).astype(np.
      ↪int)
      plotCf(target,predicted,'Cf Validation Set')
```

Acc: 0.9360000000000003



Acc: 1.0



## 1.4 Logistic Regression

```
[12]: from sklearn.linear_model import LogisticRegression
```

```
logistic_regression= LogisticRegression(fit_intercept=False)
logistic_regression.fit(x.T,(y.T).reshape(500, ))
```

```
[12]: LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=False,
    intercept_scaling=1, l1_ratio=None, max_iter=100,
    multi_class='auto', n_jobs=None, penalty='l2',
    random_state=None, solver='lbfgs', tol=0.0001, verbose=0,
    warm_start=False)
```

```
[13]: def plotCf(a,b,t):
    cf =confusion_matrix(a,b)
    plt.imshow(cf,cmap=plt.cm.Blues,interpolation='nearest')
    plt.colorbar()
    plt.title(t)
    plt.xlabel('0          Predicted          1')
    plt.ylabel('1          Actual          0')
    tick_marks = np.arange(len(set(a))) # length of classes
    class_labels = ['0','1']
    plt.xticks(np.ndarray([0,1]))
    plt.yticks(np.ndarray([0,1]))
```

```

print('Acc:',(cf[0,0]+cf[1,1])/a.shape[0])
for i,j in itertools.product(range(cf.shape[0]),range(cf.shape[1])):
    plt.
    ↳text(j,i,format(cf[i,j],'d'),horizontalalignment='center',color='white' if
    ↳cf[i,j] > (cf.max()*0.7) else 'black')
plt.show();

```

```

[14]: threshold = 0.9
y_pred = np.where(logistic_regression.predict_proba(x.T)[: ,1] > threshold, 1, 0)

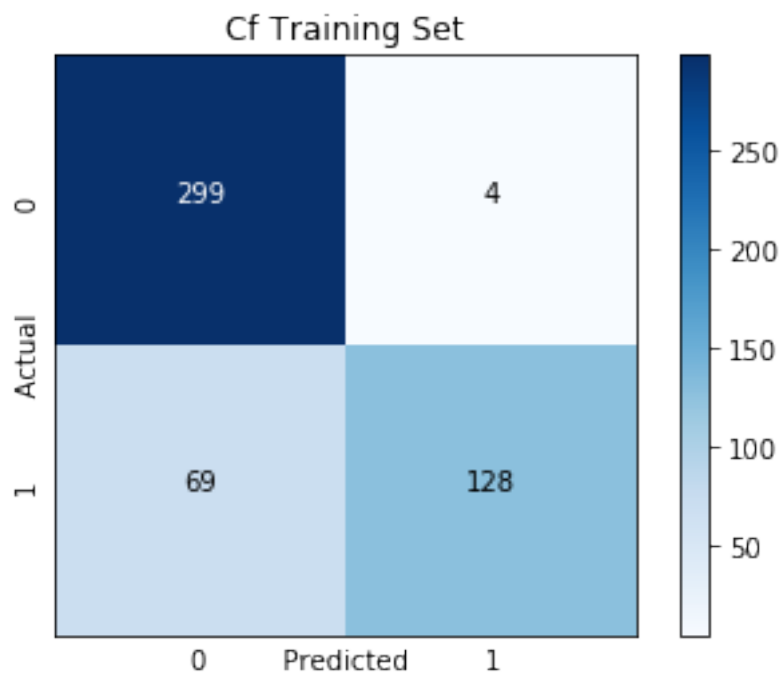
```

```

[15]: plotCf(y.reshape(500, ),y_pred,'Cf Training Set')

```

Acc: 0.854



```

[16]: threshold = 0.9
y_pred = np.where(logistic_regression.predict_proba(xval.T)[: ,1] > threshold,
    ↳1, 0)

```

```

[17]: plotCf(yval.reshape(182, ),y_pred,'Cf Validation Set')

```

Acc: 0.9175824175824175

