```
from sklearn import preprocessing # Biblioteca para suporte ao pré-processamento
from sklearn.model_selection import train_test_split # Biblioteca para separação de amostras para treino e teste
import matplotlib.pyplot as plt # Para visualizacao dos dados e do erro
import numpy as np # Biblioteca de manipulacao de arrays Numpy

class Adaline:
    def __init__(self, eta=0.001, epoch=1000, goal=0.000001):
        self.eta = eta
        self.epoch = epoch
        self.epochs = 0
        self.errorsTests = 0
        self.goal = goal

    def fit(self, X, y):
        self.weight_ = np.random.uniform(-1, 1, X.shape[1] + 1)
        self.error_ = []
        self.mse_ = []
        self.mse = 0
        self.cost = 0

        for _ in range(self.epoch):
            output = self.activation_function(X)
            error = y - output

            self.weight_[0] += self.eta * sum(error)
            self.weight_[1:] += self.eta * X.T.dot(error)

            self.cost = 1./2 * sum((error**2))
            mseP = self.mse
            self.mse = 1./X.shape[0] * sum((error**2))
            self.epochs += 1

            if self.epochs > 1:
                if mseP - self.mse < self.goal:
                    break

            self.error_.append(self.cost)
            self.mse_.append(self.mse)

        return self

    def net_input(self, X):
        return np.dot(X, self.weight_[1:]) + self.weight_[0]

    def activation_function(self, X):
        return self.net_input(X)
```

```
    def predict(self, X, y_d):
        y = np.where(self.activation_function(X) >= 0.0, 1, -1)

        if y != y_d:
            self.errorsTests += 1
            return 'Erro'
        return 'Acerto'

import pandas as pd

# Para valvulas.csv
df_valvulas = pd.read_csv('dataset/valvulas.csv', header=None)
df_valvulas.columns = ['x1', 'x2', 'x3', 'x4', 'target']

# Para valvulasTestes.csv
df_valvulas_testes = pd.read_csv('dataset/valvulasTestes.csv',
header=None)
df_valvulas_testes.columns = ['x1', 'x2', 'x3', 'x4', 'target']


df_valvulas_testes.head()
```

	x1	x2	x3	x4	target
0	0.9694	0.6909	0.4334	3.4965	-1
1	0.5427	1.3832	0.6390	4.0352	-1
2	0.6081	-0.9196	0.5925	0.1016	1
3	-0.1618	0.4694	0.2030	3.0117	-1
4	0.1870	-0.2578	0.6124	1.7749	-1

```
df_concatenado = pd.concat([df_valvulas, df_valvulas_testes],
ignore_index=True)

df_concatenado
```

	x1	x2	x3	x4	target
0	0.4329	-1.3719	0.7022	-0.8535	1.0
1	0.3024	0.2286	0.8630	2.7909	-1.0
2	0.1349	-0.6445	1.0530	0.5687	-1.0
3	0.3374	-1.7163	0.3670	-0.6283	-1.0
4	1.1434	-0.0485	0.6637	1.2606	1.0
5	1.3749	-0.5071	0.4464	1.3009	1.0
6	0.7221	-0.7587	0.7681	-0.5592	1.0
7	0.4403	-0.8072	0.5154	-0.3129	1.0
8	-0.5231	0.3548	0.2538	1.5776	-1.0
9	0.3255	-2.0000	0.7112	-1.1209	1.0
10	0.5824	1.3915	-0.2291	4.1735	-1.0
11	0.1340	0.6081	0.4450	3.2230	-1.0
12	0.1480	-0.2988	0.4778	0.8649	1.0
13	0.7359	0.1869	-0.0872	2.3584	1.0
14	0.7115	-1.1469	0.3394	0.9573	-1.0
15	0.8251	-1.2840	0.8452	1.2382	-1.0

```
16  0.1569  0.3712  0.8825  1.7633     1.0
17  0.0033  0.6835  0.5389  2.8249    -1.0
18  0.4243  0.8313  0.2634  3.5855    -1.0
19  1.0490  0.1326  0.9138  1.9792     1.0
20  1.4276  0.5331 -0.0145  3.7286     1.0
21  0.5971  1.4865  0.2904  4.6069    -1.0
22  0.8475  2.1479  0.3179  5.8235    -1.0
23  1.3967 -0.4171  0.6443  1.3927     1.0
24  0.0044  1.5378  0.6099  4.7755    -1.0
25  0.2201 -0.5668  0.0515  0.7829     1.0
26  0.6300 -1.2480  0.8591  0.8093    -1.0
27 -0.2479  0.8960  0.0547  1.7381     1.0
28 -0.3088 -0.0929  0.8659  1.5483    -1.0
29 -0.5180  1.4974  0.5453  2.3993     1.0
30  0.6833  0.8266  0.0829  2.8864     1.0
31  0.4353 -1.4066  0.4207 -0.4879     1.0
32 -0.1069 -3.2329  0.1856 -2.4572    -1.0
33  0.4662  0.6261  0.7304  3.4370    -1.0
34  0.8298 -1.4089  0.3119  1.3235    -1.0
35  0.9694  0.6909  0.4334  3.4965    -1.0
36  0.5427  1.3832  0.6390  4.0352    -1.0
37  0.6081 -0.9196  0.5925  0.1016     1.0
38 -0.1618  0.4694  0.2030  3.0117    -1.0
39  0.1870 -0.2578  0.6124  1.7749    -1.0
40  0.4891 -0.5276  0.4378  0.6439     1.0
41  0.3777  2.0149  0.7423  3.3932     1.0
42  1.1498 -0.4067  0.2469  1.5866     1.0
43  0.9325  1.0950  1.0359  3.3591     1.0
44  0.5060  1.3317  0.9222  3.7174    -1.0
45  0.0497 -2.0656  0.6124 -0.6585    -1.0
46  0.4004  3.5369  0.9766  5.3532     1.0
47 -0.1874  1.3343  0.5374  3.2189    -1.0
48  0.5060  1.3317  0.9222  3.7174    -1.0
49  1.6375 -0.7911  0.7537  0.5515     1.0
```

```
# Preparar os dados para plotagem
X = df_concatenado[['x2', 'x1', "x3", 'x4']].values
y = df_concatenado['target'].values
```

```
X
```

```
array([[-1.3719e+00,  4.3290e-01,  7.0220e-01, -8.5350e-01],
       [ 2.2860e-01,  3.0240e-01,  8.6300e-01,  2.7909e+00],
       [-6.4450e-01,  1.3490e-01,  1.0530e+00,  5.6870e-01],
       [-1.7163e+00,  3.3740e-01,  3.6700e-01, -6.2830e-01],
       [-4.8500e-02,  1.1434e+00,  6.6370e-01,  1.2606e+00],
       [-5.0710e-01,  1.3749e+00,  4.4640e-01,  1.3009e+00],
       [-7.5870e-01,  7.2210e-01,  7.6810e-01, -5.5920e-01],
       [-8.0720e-01,  4.4030e-01,  5.1540e-01, -3.1290e-01],
       [ 3.5480e-01, -5.2310e-01,  2.5380e-01,  1.5776e+00],
```

```
       [-2.0000e+00,  3.2550e-01,  7.1120e-01, -1.1209e+00],
       [ 1.3915e+00,  5.8240e-01, -2.2910e-01,  4.1735e+00],
       [ 6.0810e-01,  1.3400e-01,  4.4500e-01,  3.2230e+00],
       [-2.9880e-01,  1.4800e-01,  4.7780e-01,  8.6490e-01],
       [ 1.8690e-01,  7.3590e-01, -8.7200e-02,  2.3584e+00],
       [-1.1469e+00,  7.1150e-01,  3.3940e-01,  9.5730e-01],
       [-1.2840e+00,  8.2510e-01,  8.4520e-01,  1.2382e+00],
       [ 3.7120e-01,  1.5690e-01,  8.8250e-01,  1.7633e+00],
       [ 6.8350e-01,  3.3000e-03,  5.3890e-01,  2.8249e+00],
       [ 8.3130e-01,  4.2430e-01,  2.6340e-01,  3.5855e+00],
       [ 1.3260e-01,  1.0490e+00,  9.1380e-01,  1.9792e+00],
       [ 5.3310e-01,  1.4276e+00, -1.4500e-02,  3.7286e+00],
       [ 1.4865e+00,  5.9710e-01,  2.9040e-01,  4.6069e+00],
       [ 2.1479e+00,  8.4750e-01,  3.1790e-01,  5.8235e+00],
       [-4.1710e-01,  1.3967e+00,  6.4430e-01,  1.3927e+00],
       [ 1.5378e+00,  4.4000e-03,  6.0990e-01,  4.7755e+00],
       [-5.6680e-01,  2.2010e-01,  5.1500e-02,  7.8290e-01],
       [-1.2480e+00,  6.3000e-01,  8.5910e-01,  8.0930e-01],
       [ 8.9600e-01, -2.4790e-01,  5.4700e-02,  1.7381e+00],
       [-9.2900e-02, -3.0880e-01,  8.6590e-01,  1.5483e+00],
       [ 1.4974e+00, -5.1800e-01,  5.4530e-01,  2.3993e+00],
       [ 8.2660e-01,  6.8330e-01,  8.2900e-02,  2.8864e+00],
       [-1.4066e+00,  4.3530e-01,  4.2070e-01, -4.8790e-01],
       [-3.2329e+00, -1.0690e-01,  1.8560e-01, -2.4572e+00],
       [ 6.2610e-01,  4.6620e-01,  7.3040e-01,  3.4370e+00],
       [-1.4089e+00,  8.2980e-01,  3.1190e-01,  1.3235e+00],
       [ 6.9090e-01,  9.6940e-01,  4.3340e-01,  3.4965e+00],
       [ 1.3832e+00,  5.4270e-01,  6.3900e-01,  4.0352e+00],
       [-9.1960e-01,  6.0810e-01,  5.9250e-01,  1.0160e-01],
       [ 4.6940e-01, -1.6180e-01,  2.0300e-01,  3.0117e+00],
       [-2.5780e-01,  1.8700e-01,  6.1240e-01,  1.7749e+00],
       [-5.2760e-01,  4.8910e-01,  4.3780e-01,  6.4390e-01],
       [ 2.0149e+00,  3.7770e-01,  7.4230e-01,  3.3932e+00],
       [-4.0670e-01,  1.1498e+00,  2.4690e-01,  1.5866e+00],
       [ 1.0950e+00,  9.3250e-01,  1.0359e+00,  3.3591e+00],
       [ 1.3317e+00,  5.0600e-01,  9.2220e-01,  3.7174e+00],
       [-2.0656e+00,  4.9700e-02,  6.1240e-01, -6.5850e-01],
       [ 3.5369e+00,  4.0040e-01,  9.7660e-01,  5.3532e+00],
       [ 1.3343e+00, -1.8740e-01,  5.3740e-01,  3.2189e+00],
       [ 1.3317e+00,  5.0600e-01,  9.2220e-01,  3.7174e+00],
       [-7.9110e-01,  1.6375e+00,  7.5370e-01,  5.5150e-01]])

scaler = preprocessing.MinMaxScaler()

y

array([ 1., -1., -1., -1.,  1.,  1.,  1.,  1., -1.,  1., -1., -1.,
1.,
        1., -1., -1.,  1., -1., -1.,  1.,  1., -1., -1.,  1., -1.,
1.,
```

```
       -1.,  1., -1.,  1.,  1.,  1., -1., -1., -1., -1., -1.,  1., -
1.,
       -1.,  1.,  1.,  1.,  1., -1., -1.,  1., -1., -1.,  1.])
```

```
X = scaler.fit_transform(X)
```

```
X
```

```
array([[0.27489734, 0.44246968, 0.7263864 , 0.1936672 ],
       [0.51131496, 0.3820698 , 0.85180563, 0.63377492],
       [0.38234512, 0.30454503, 1.        , 0.36541597],
       [0.22402434, 0.398269  , 0.46494033, 0.22086297],
       [0.47038317, 0.77131352, 0.69635754, 0.44897171],
       [0.40264114, 0.87845969, 0.52686998, 0.45383844],
       [0.36547608, 0.57632139, 0.77778644, 0.22920768],
       [0.35831191, 0.44589466, 0.58068793, 0.25895154],
       [0.52995657, 0.        , 0.37664769, 0.48725349],
       [0.18211764, 0.39276127, 0.73340613, 0.16137525],
       [0.68309256, 0.51166343, 0.        , 0.80074148],
       [0.56737274, 0.30412848, 0.52577802, 0.6859565 ],
       [0.43341015, 0.31060816, 0.55136105, 0.40118589],
       [0.50515525, 0.58270851, 0.11067779, 0.58154504],
       [0.30813318, 0.57141535, 0.44341315, 0.41234437],
       [0.28788147, 0.62399334, 0.83792216, 0.44626662],
       [0.5323791 , 0.31472739, 0.86701505, 0.50967913],
       [0.57851044, 0.24363603, 0.59901724, 0.63788086],
       [0.6003427 , 0.43848931, 0.3841354 , 0.72973299],
       [0.49713433, 0.72762196, 0.89142813, 0.53575181],
       [0.55629413, 0.90285106, 0.16738164, 0.74701414],
       [0.69712547, 0.51846709, 0.4051946 , 0.85308005],
       [0.79482407, 0.63436083, 0.42664379, 1.        ],
       [0.41593548, 0.88854948, 0.68122611, 0.46492446],
       [0.70470324, 0.24414514, 0.65439513, 0.87344065],
       [0.39382256, 0.34397852, 0.21885968, 0.39128335],
       [0.29319921, 0.53369434, 0.84876375, 0.39447148],
       [0.60989985, 0.12737203, 0.22135559, 0.50663591],
       [0.46382463, 0.09918541, 0.85406755, 0.48371514],
       [0.69873556, 0.00236046, 0.60400905, 0.58648423],
       [0.59964844, 0.55836342, 0.24335075, 0.64530776],
       [0.26977163, 0.44358049, 0.50682474, 0.23781806],
       [0.        , 0.19263168, 0.32345371, 0.        ],
       [0.57003161, 0.45788207, 0.74838156, 0.71179973],
       [0.26943189, 0.62616866, 0.42196397, 0.45656768],
       [0.57960353, 0.69078034, 0.51673036, 0.71898511],
       [0.68186652, 0.4932889 , 0.67709227, 0.78404   ],
       [0.34170877, 0.52355827, 0.64082365, 0.30900769],
       [0.54688469, 0.16722207, 0.33702519, 0.66043933],
       [0.43946645, 0.32865871, 0.65634506, 0.51107998],
       [0.39961299, 0.46848098, 0.52016223, 0.37449733],
       [0.775178  , 0.41692123, 0.75766321, 0.70651032],
```

```
       [0.41747171, 0.77427566, 0.37126589, 0.48834036],
       [0.6392951 , 0.67370175, 0.98666251, 0.70239231],
       [0.67425921, 0.47630288, 0.89797988, 0.7456616 ],
       [0.17242755, 0.26511154, 0.65634506, 0.21721594],
       [1.        , 0.42742757, 0.94041026, 0.94320528],
       [0.67464327, 0.15537351, 0.59784728, 0.68546137],
       [0.67425921, 0.47630288, 0.89797988, 0.7456616 ],
       [0.36069012, 1.        , 0.76655487, 0.36333885]])
```

```
X_train, X_test, y_train, y_test = train_test_split(X, y,
test_size=0.30)
```

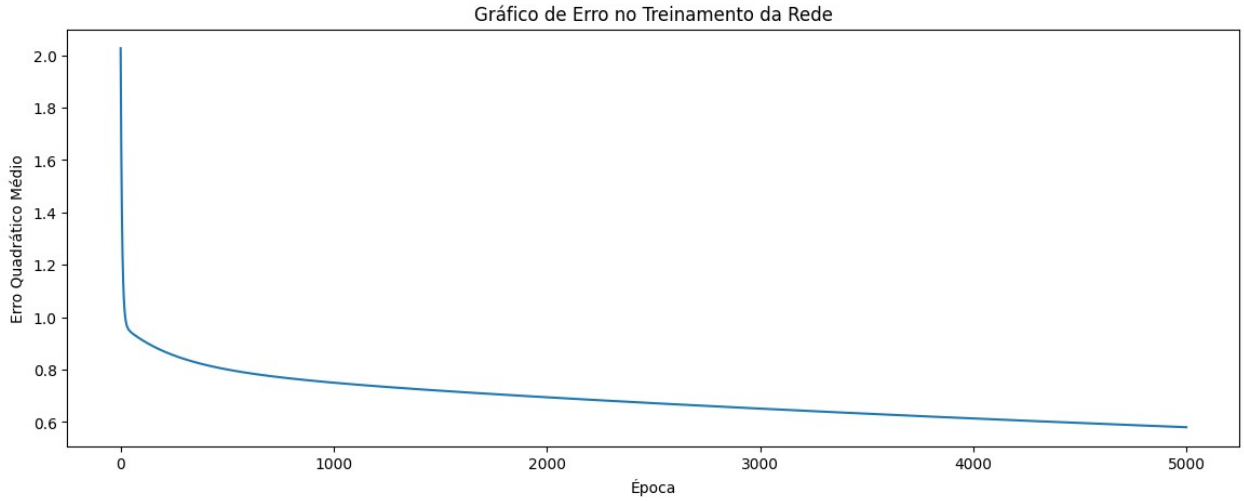
```
X_test
```

```
array([[0.27489734, 0.44246968, 0.7263864 , 0.1936672 ],
       [0.26943189, 0.62616866, 0.42196397, 0.45656768],
       [0.41593548, 0.88854948, 0.68122611, 0.46492446],
       [0.67425921, 0.47630288, 0.89797988, 0.7456616 ],
       [0.        , 0.19263168, 0.32345371, 0.        ],
       [0.52995657, 0.        , 0.37664769, 0.48725349],
       [0.36547608, 0.57632139, 0.77778644, 0.22920768],
       [0.57960353, 0.69078034, 0.51673036, 0.71898511],
       [0.35831191, 0.44589466, 0.58068793, 0.25895154],
       [0.51131496, 0.3820698 , 0.85180563, 0.63377492],
       [0.57003161, 0.45788207, 0.74838156, 0.71179973],
       [0.775178  , 0.41692123, 0.75766321, 0.70651032],
       [0.29319921, 0.53369434, 0.84876375, 0.39447148],
       [1.        , 0.42742757, 0.94041026, 0.94320528],
       [0.70470324, 0.24414514, 0.65439513, 0.87344065]])
```

```
rede = Adaline(eta = 0.001, epoch = 5000, goal = 0.000001)
rede.fit(X_train, y_train)
```

```
<__main__.Adaline at 0x7e20191c00d0>
```

```
# Plotando o gráfico da descida do gradiente no processo de
treinamento
plt.figure(figsize=(14,5))
ax = plt.subplot()
ax.plot(range(len(rede.mse_)), rede.mse_)
ax.set_ylabel('Erro Quadrático Médio')
ax.set_xlabel('Época')
ax.set_title('Gráfico de Erro no Treinamento da Rede')
plt.show()
```




```
# Testando a rede em lote de amostras
print("\nClassificações dos testes com amostras não apresentadas no
treinamento:")

# For entrada, saida in zip(X_test, y_test):
nTests = len(y_test)
for i in range(nTests):
    rede.predict(X_test[i,:], y_test[i])

print("Acurácia: ", (nTests-rede.errorsTests)/nTests*100, "%")
print("Quantidade de erros no teste em lote: ", rede.errorsTests)
print("Número de épocas do treinamento da RNA: ", rede.epochs)
print("Erro quadrático médio final (MSE - Eqm(w)): ", rede.mse)
print("Erro quadrático final (QE - E(w) - Custo): ", rede.cost)
print("Vetor de pesos finais da RNA treinada - Limiar = ",
rede.weight_[0], "Pesos das entradas = ", rede.weight_[1:])
```

```
Classificações dos testes com amostras não apresentadas no
treinamento:
Acurácia:  66.66666666666666 %
Quantidade de erros no teste em lote:  5
Número de épocas do treinamento da RNA:  5000
Erro quadrático médio final (MSE - Eqm(w)):  0.580293541472354
Erro quadrático final (QE - E(w) - Custo):  10.155136975766196
Vetor de pesos finais da RNA treinada - Limiar =  0.3097888486601299
Pesos das entradas =  [ 2.44548896  1.75942841 -0.66207277 -
3.6117866 ]
```

```
0.309
```

```
import numpy as np

# Criando amostras individuais
A = np.array([0.698, 0.002, 0.604, 0.586])  # Exemplo de amostra com
```

```
padrão desejado de -1
A_y = np.array(-1)
B = np.array([0.687, 0.528, 0.405 , 0.823])  # Exemplo de amostra com
padrão desejado de 1
B_y = np.array(1)

print("Apresentação dos testes individuais:")
print ("Amostra A - Padrão desejado = -1 -> ", rede.predict(A, A_y))
print ("Amostra B - Padrão desejado = 1 -> ", rede.predict(B, B_y))
```

```
Apresentação dos testes individuais:
Amostra A - Padrão desejado = -1 ->  Acerto
Amostra B - Padrão desejado = 1 ->  Acerto
```

```
import pandas as pd

data = {
    'Amostra': [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15],
    'x1': [0.9694, 0.5427, 0.6081, -0.1618, 0.1870, 0.4891, 0.3777,
1.1498, 0.9325, 0.5060, 0.0497, 0.4004, -0.1874, 0.5060, 1.6375],
    'x2': [0.6909, 1.3832, -0.9196, 0.4694, -0.2578, -0.5276, 2.0149,
-0.4067, 1.0950, 1.3317, -2.0656, 3.5369, 1.3343, 1.3317, -0.7911],
    'x3': [0.4334, 0.6390, 0.5925, 0.2030, 0.6124, 0.4378, 0.7423,
0.2469, 1.0359, 0.9222, 0.6124, 0.9766, 0.5374, 0.9222, 0.7537],
    'x4': [3.4965, 4.0352, 0.1016, 3.0117, 1.7749, 0.6439, 3.3932,
1.5866, 3.3591, 3.7174, -0.6585, 5.3532, 3.2189, 3.7174, 0.5515],
    'd': [-1, -1, 1, -1, -1, 1, 1, 1, 1, 1, -1, 1, -1, -1, 1],
    'y': ['T1', 'T1', 'T2', 'T1', 'T1', 'T2', 'T2', 'T2', 'T2', 'T1',
'T1', 'T2', 'T1', 'T1', 'T2']
}

base_test = pd.DataFrame(data)

print(base_test)
```

```
    Amostra      x1      x2      x3      x4  d   y
0         1  0.9694  0.6909  0.4334  3.4965 -1  T1
1         2  0.5427  1.3832  0.6390  4.0352 -1  T1
2         3  0.6081 -0.9196  0.5925  0.1016  1  T2
3         4 -0.1618  0.4694  0.2030  3.0117 -1  T1
4         5  0.1870 -0.2578  0.6124  1.7749 -1  T1
5         6  0.4891 -0.5276  0.4378  0.6439  1  T2
6         7  0.3777  2.0149  0.7423  3.3932  1  T2
7         8  1.1498 -0.4067  0.2469  1.5866  1  T2
8         9  0.9325  1.0950  1.0359  3.3591  1  T2
9        10  0.5060  1.3317  0.9222  3.7174  1  T1
10       11  0.0497 -2.0656  0.6124 -0.6585 -1  T1
11       12  0.4004  3.5369  0.9766  5.3532  1  T2
12       13 -0.1874  1.3343  0.5374  3.2189 -1  T1
```

```
13       14  0.5060  1.3317  0.9222  3.7174 -1  T1
14       15  1.6375 -0.7911  0.7537  0.5515  1  T2
```

```
def Inference(row):
    base = np.array([row['x1'], row['x2'], row['x3'], row['x4']])
    return rede.predict(base, row['d'])

base_test['T1'] = base_test[['x1', 'x2', 'x3', 'x4',
'd']].apply(Inference, axis=1)

base_test
```

```
    Amostra      x1      x2      x3      x4  d   y      T1
0         1  0.9694  0.6909  0.4334  3.4965 -1  T1  Acerto
1         2  0.5427  1.3832  0.6390  4.0352 -1  T1  Acerto
2         3  0.6081 -0.9196  0.5925  0.1016  1  T2    Erro
3         4 -0.1618  0.4694  0.2030  3.0117 -1  T1  Acerto
4         5  0.1870 -0.2578  0.6124  1.7749 -1  T1  Acerto
5         6  0.4891 -0.5276  0.4378  0.6439  1  T2    Erro
6         7  0.3777  2.0149  0.7423  3.3932  1  T2    Erro
7         8  1.1498 -0.4067  0.2469  1.5866  1  T2    Erro
8         9  0.9325  1.0950  1.0359  3.3591  1  T2    Erro
9        10  0.5060  1.3317  0.9222  3.7174  1  T1    Erro
10       11  0.0497 -2.0656  0.6124 -0.6585 -1  T1  Acerto
11       12  0.4004  3.5369  0.9766  5.3532  1  T2    Erro
12       13 -0.1874  1.3343  0.5374  3.2189 -1  T1  Acerto
13       14  0.5060  1.3317  0.9222  3.7174 -1  T1  Acerto
14       15  1.6375 -0.7911  0.7537  0.5515  1  T2  Acerto
```