Project3

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Machine Learning

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1 Designing Multi Layer Perceptron (MLP)

We define a layer as a Class with a specific properties

Each layer is capable of performing two things:

1. Process input to get output: output = layer.forward(input)
2. Propagate gradients through itself: grad_input = layer.backward(input, grad_output)

[26]:
```
import numpy as np
import keras
import matplotlib.pyplot as plt
from tqdm import trange
from IPython.display import clear_output


class ReLU():
    def __init__(self):
        pass

    def forward(self, input):
        relu_forward = np.maximum(0,input)
        return relu_forward

    def backward(self, input, grad_output):
        relu_grad = input > 0
        return grad_output*relu_grad


class Dense():
    def __init__(self, input_units, output_units, learning_rate=0.1):
```

```
        self.learning_rate = learning_rate
        self.weights = np.random.normal(loc=0.0, scale = np.sqrt(2/(input_units+output_units)), size = (input_units,output_units))
        self.biases = np.zeros(output_units)

    def forward(self,input):
        return np.dot(input,self.weights) + self.biases

    def backward(self,input,grad_output):
        grad_input = np.dot(grad_output, self.weights.T)
        grad_weights = np.dot(input.T, grad_output)
        grad_biases = grad_output.mean(axis=0)*input.shape[0]

        self.weights = self.weights - self.learning_rate * grad_weights
        self.biases = self.biases - self.learning_rate * grad_biases

        return grad_input

def softmax_crossentropy_with_logits(logits,reference_answers):
    logits_for_answers = logits[np.arange(len(logits)),reference_answers]
    xentropy = - logits_for_answers + np.log(np.sum(np.exp(logits),axis=-1))
    return xentropy

def grad_softmax_crossentropy_with_logits(logits,reference_answers):
    ones_for_answers = np.zeros_like(logits)
    ones_for_answers[np.arange(len(logits)),reference_answers] = 1
    softmax = np.exp(logits) / np.exp(logits).sum(axis=-1,keepdims=True)
    return (- ones_for_answers + softmax) / logits.shape[0]

def forward(network, X):
    activations = []
    input = X
    for l in network:
        activations.append(l.forward(input))
        input = activations[-1]
    return activations

def predict(network,X):
    # Compute network predictions. Returning indices of largest Logit probability
    logits = forward(network,X)[-1]
    return logits.argmax(axis=-1)

def train(network,X,y):
    # Get the layer activations
    layer_activations = forward(network,X)
```

```
    layer_inputs = [X]+layer_activations  #layer_input[i] is an input for␣
↪network[i]
    logits = layer_activations[-1]

    # Compute the loss and the initial gradient
    loss = softmax_crossentropy_with_logits(logits,y)
    loss_grad = grad_softmax_crossentropy_with_logits(logits,y)

    # Propagate gradients through the network
    # Reverse propogation as this is backprop
    for layer_index in range(len(network))[::-1]:
        layer = network[layer_index]

        loss_grad = layer.backward(layer_inputs[layer_index],loss_grad) #grad w.
↪r.t. input, also weight updates

    return np.mean(loss)
```

Here we will :

1. import the Heart Disease dataset and perform a data cleaning on the rows that have invalid numbers (-100000) in the "ca" or "thal" columns

2. Split the data columns into X and y.

3. Normalize the values of input X.

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[27]:
```
import pandas as pd
from sklearn.preprocessing import MinMaxScaler

df = pd.read_excel('Heart_Disease.xls', sheet_name='data')
df = df[df.ca != -100000]
df = df[df.thal != -100000]

y = df['num']
X = df.drop(columns=['num'])

scaler_x = MinMaxScaler()
scaler_x.fit(X)
X = scaler_x.transform(X)

y = y.values.reshape(-1, 1)
scaler_y = MinMaxScaler()
scaler_y.fit_transform(y)
y = scaler_y.transform(y)[:,0].astype('int')
```

```
y
```

[27]:
```
array([0, 1, 1, 0, 0, 0, 1, 0, 1, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0, 0,
       1, 1, 1, 0, 0, 0, 0, 1, 0, 1, 1, 0, 0, 0, 1, 1, 1, 0, 1, 0, 0, 0,
       1, 1, 0, 1, 0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 0, 0, 1, 0, 1, 0, 1, 1,
       1, 0, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0, 0, 1, 0, 0, 0, 1, 0, 0, 0, 0,
       0, 0, 1, 0, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 0, 1, 1, 1, 1, 1,
       1, 0, 1, 1, 0, 0, 0, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 0, 0, 0, 0, 0,
       0, 0, 0, 1, 1, 1, 0, 0, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1,
       1, 1, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 0, 1,
       0, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1, 0, 1, 0, 0, 0, 1, 0,
       0, 0, 0, 0, 1, 1, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0,
       1, 1, 0, 0, 0, 1, 1, 0, 1, 1, 0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 1, 0,
       1, 1, 1, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 1, 1, 1,
       1, 0, 1, 0, 1, 0, 1, 0, 0, 0, 1, 0, 1, 0, 1, 0, 1, 1, 1, 0, 0, 1,
       0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1])
```

Let's split the data to train, validation and test sets

---

[28]:
```
from sklearn.model_selection import train_test_split

X_train, X_validation, y_train, y_validation = train_test_split(X, y,␣
 ↪test_size=0.3)
X_validation, X_test, y_validation, y_test = train_test_split(X_validation,␣
 ↪y_validation, test_size=0.5)
```

Its time to create the Network

We will add 2 hidden layers with 100 and 200 nodes and the ReLU activation layers between them

Then the model will be trained in 50 epochs and the Train and Accuracy will be ploted.

---

[37]:
```
network = []
network.append(Dense(X_train.shape[1],100))
network.append(ReLU())
network.append(Dense(100,200))
network.append(ReLU())
network.append(Dense(200,6))

train_log = []
val_log = []
```

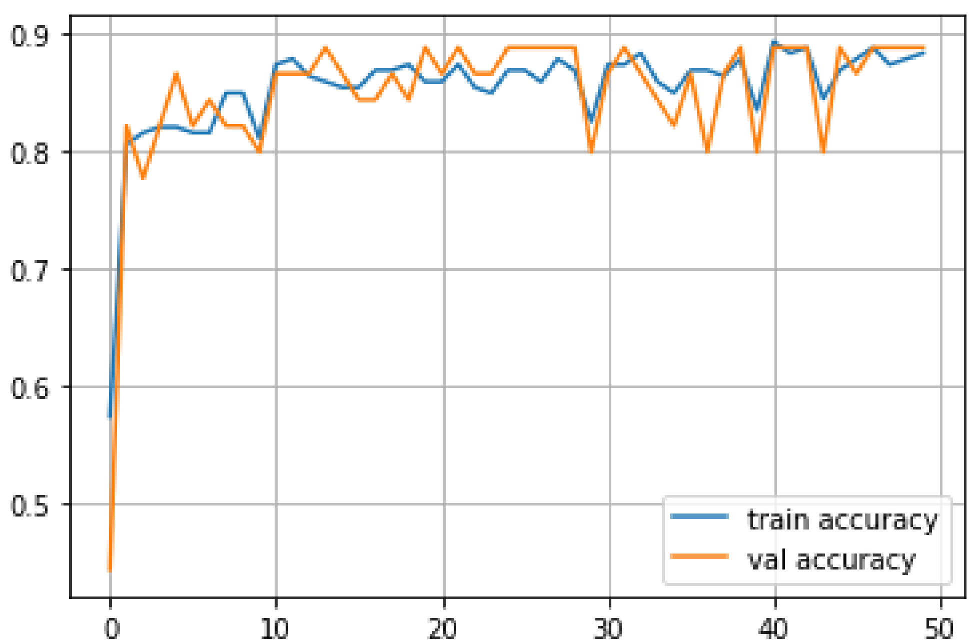
```python
batchsize=20

for epoch in range(50):
    indices = np.random.permutation(len(X_train))
    for start_idx in range(0, len(X_train) - batchsize + 1, batchsize):
        excerpt = indices[start_idx:start_idx + batchsize]
        x_batch = X_train[excerpt]
        y_batch = y_train[excerpt]
        train(network,x_batch,y_batch)

    train_log.append(np.mean(predict(network,X_train)==y_train))
    val_log.append(np.mean(predict(network,X_validation)==y_validation))

    clear_output()
    print("Epoch",epoch)
    print("Train accuracy:",train_log[-1])
    print("Val accuracy:",val_log[-1])
    plt.plot(train_log,label='train accuracy')
    plt.plot(val_log,label='val accuracy')
    plt.legend(loc='best')
    plt.grid()
    plt.show()
```

```
Epoch 49
Train accuracy: 0.8840579710144928
Val accuracy: 0.8888888888888888
```



Now we will test our trained model and report the metrics

```
[38]: from sklearn.metrics import classification_report

y_predict = predict(network,X_test)
target_names = ['sick', 'healthy']

print(classification_report(y_test, y_predict, target_names=target_names))
```

```
              precision    recall  f1-score   support

        sick       0.72      0.86      0.78        21
     healthy       0.85      0.71      0.77        24

    accuracy                           0.78        45
   macro avg       0.78      0.78      0.78        45
weighted avg       0.79      0.78      0.78        45
```

In the final step we will do all the stuff again with the Soccer History Dataset and report the metrics

```
[40]: import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import OneHotEncoder
from sklearn.preprocessing import MinMaxScaler
from sklearn.metrics import classification_report


df = pd.read_excel('soccer_international_history_dataset.xlsx',␣
 ↪sheet_name='data')

categorical_columns = ['home_country', 'away_country', 'match_type',␣
 ↪'match_city', 'match_country']
categorical_prefix = ['home_country_', 'away_country_', 'match_type_',␣
 ↪'match_city_', 'match_country_']

encoder = OneHotEncoder(handle_unknown='ignore')

for column in categorical_columns:
    df[column] = df[column].astype('category')
```

```
X = pd.get_dummies(df, columns=categorical_columns, prefix=categorical_prefix)

X = X.drop(columns=['home_team_result', 'match_date'])

y = df['home_team_result']
y = pd.get_dummies(y, columns=['home_team_result'], prefix='home_team_result_')

y = np.argmax(y.values, axis=1)

display(y)

X_columns = X.columns

scaler_x = MinMaxScaler()
scaler_x.fit(X)
X = scaler_x.transform(X)

# y = y.reshape(-1, 1)
# scaler_y = MinMaxScaler()
# scaler_y.fit_transform(y)
# y = scaler_y.transform(y)

X_train, X_validation, y_train, y_validation = train_test_split(X, y,␣
↪test_size=0.3)
X_validation, X_test, y_validation, y_test = train_test_split(X_validation,␣
↪y_validation, test_size=0.5)

network = []
network.append(Dense(X_train.shape[1],100))
network.append(ReLU())
network.append(Dense(100,200))
network.append(ReLU())
network.append(Dense(200,3))

train_log = []
val_log = []
batchsize=20

for epoch in range(50):
    indices = np.random.permutation(len(X_train))
    for start_idx in range(0, len(X_train) - batchsize + 1, batchsize):
        excerpt = indices[start_idx:start_idx + batchsize]
        x_batch = X_train[excerpt]
        y_batch = y_train[excerpt]
        train(network,x_batch,y_batch)
```

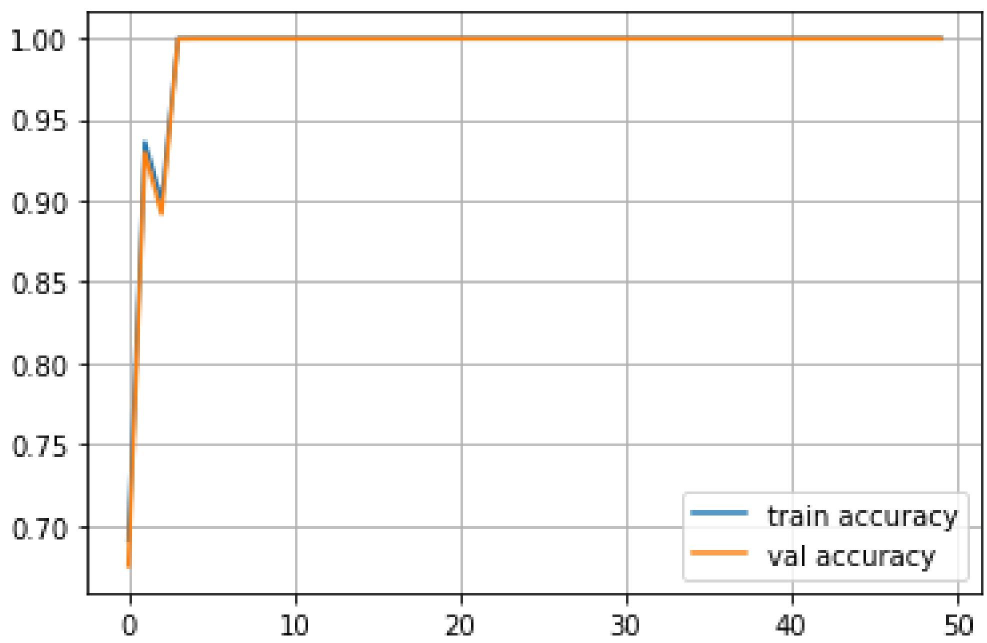
```python
    train_log.append(np.mean(predict(network,X_train)==y_train))
    val_log.append(np.mean(predict(network,X_validation)==y_validation))

    clear_output()
    print("Epoch",epoch)
    print("Train accuracy:",train_log[-1])
    print("Val accuracy:",val_log[-1])
    plt.plot(train_log,label='train accuracy')
    plt.plot(val_log,label='val accuracy')
    plt.legend(loc='best')
    plt.grid()
    plt.show()

y_predict = predict(network,X_test)
target_names = ['Loss', 'Draw', 'Win']

print(classification_report(y_test, y_predict, target_names=target_names))
```

```
Epoch 49
Train accuracy: 1.0
Val accuracy: 0.9998276753403412
```




```
              precision    recall  f1-score   support

        Loss       1.00      1.00      1.00      1292
        Draw       1.00      1.00      1.00      1717
```

Win	1.00	1.00	1.00	2794
accuracy			1.00	5803
macro avg	1.00	1.00	1.00	5803
weighted avg	1.00	1.00	1.00	5803