ML perceptron learning rule (P2)

v0.1

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Chapter 1

ML-Perceptron-learning-rule

1.1 Student

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1.2 Introduction

In this repository, we will implement and test a perceptron using the learning rule. This will be demonstrated by creating AND and XOR gates and by evaluating the perceptron's ability to classify the `Iris dataset`. The performance will be measured using the `MSE` metric. You can find the assignment `here`.

1.3 Documentation

For this assignment, the documentation was generated with Doxygen. The LaTeX documentation is available `here` and, to view the HTML documentation locally, open `index.html` in a browser.

1.4 Installing

Enter the test directory and then Generate build files:

```
cmake -S . -B build
```

Build the project:

```
cmake --build build
```

Run the executable:

```
./build/MLPerceptronTest
```

Chapter 2

Class Index

2.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 3

File Index

3.1 File List

Here is a list of all documented files with brief descriptions:

Chapter 4

Class Documentation

4.1 irisData Struct Reference

A structure to hold the features and targets read from a CSV file. This is fdor the iris data set.

`#include <csv_reader.hpp>`

Public Attributes

- std::vector< std::vector< float > > features
- std::vector< int > targets

4.1.1 Detailed Description

A structure to hold the features and targets read from a CSV file. This is fdor the iris data set.

This structure contains two members:

- features: A 2D vector of floats where each inner vector represents a set of features for a single data point.
- targets: A vector of integers where each element represents the target value corresponding to the features.

Definition at line 18 of file csv_reader.hpp.

4.1.2 Member Data Documentation

4.1.2.1 features

`std::vector<std::vector<float> > irisData::features`

Definition at line 27 of file csv_reader.hpp.

4.1.2.2 targets

```
std::vector<int> irisData::targets
```

Definition at line 28 of file csv_reader.hpp.

The documentation for this struct was generated from the following file:

- /Users/stanislav/Github/MachineLearning/ML-perceptron-learning-rule/src/header/csv_reader.hpp

4.2 Perceptron Class Reference

A simple perceptron model for binary classification.

```
#include <perceptron.hpp>
```

Public Member Functions

- Perceptron (std::vector< double > weights, double bias, double learningRate)
  Constructs a Perceptron with given weights, bias, and learning rate.
- int predict (const std::vector< float > &x) const
  Predicts the output for a given input vector.
- void update (const std::vector< std::vector< float > > &inputs, const std::vector< int > &targets, int epochs)
  Trains the perceptron using the given dataset. Using the learning rule to update the weights.
- double loss (const std::vector< std::vector< float > > &inputs, const std::vector< int > &targets) const
  Calculates the loss of the perceptron. Based of the Mean Squared Error (MSE).
- void __str__ (int verbose) const
  Prints perceptron details.

4.2.1 Detailed Description

A simple perceptron model for binary classification.

Definition at line 20 of file perceptron.hpp.

4.2.2 Constructor & Destructor Documentation

4.2.2.1 Perceptron()

```
Perceptron::Perceptron (
            std::vector< double > weights,
            double bias,
            double learningRate)
```

Constructs a Perceptron with given weights, bias, and learning rate.

Parameters

weights	Initial weights.
bias	Initial bias.
learningRate	Learning rate for training.

Definition at line 13 of file perceptron.cpp.

4.2.3 Member Function Documentation

4.2.3.1 __str__()

```
void Perceptron::__str__ (
            int verbose) const
```

Prints perceptron details.

Parameters

verbose	Verbosity level.

Definition at line 61 of file perceptron.cpp.

4.2.3.2 loss()

```
double Perceptron::loss (
            const std::vector< std::vector< float > > & inputs,
            const std::vector< int > & targets) const
```

Calculates the loss of the perceptron. Based of the Mean Squared Error (MSE).

Parameters

inputs	Input vector for all posible inputs.
targets	Target vector for all posible inputs.

Returns

double

Definition at line 50 of file perceptron.cpp.

4.2.3.3 predict()

```
int Perceptron::predict (
            const std::vector< float > & x) const
```

Predicts the output for a given input vector.

Parameters

inputs	Input vector.

Returns

1 if activated, otherwise 0.

Definition at line 16 of file perceptron.cpp.

4.2.3.4 update()

```
void Perceptron::update (
            const std::vector< std::vector< float > > & inputs,
            const std::vector< int > & targets,
            int epochs)
```

Trains the perceptron using the given dataset. Using the learning rule to update the weights.

Parameters

inputs	Input samples.
targets	Target outputs.
epochs	Number of training iterations.

Definition at line 27 of file perceptron.cpp.

The documentation for this class was generated from the following files:

- /Users/stanislav/Github/MachineLearning/ML-perceptron-learning-rule/src/header/perceptron.hpp
- /Users/stanislav/Github/MachineLearning/ML-perceptron-learning-rule/src/perceptron.cpp

Chapter 5

File Documentation

5.1 /Users/stanislav/Github/MachineLearning/ML-perceptron-learning-rule/importing_dataset.py File Reference

Script to import and save the Iris dataset.

Variables

- importing_dataset.iris = load_iris()

5.1.1 Detailed Description

Script to import and save the Iris dataset.

This script uses scikit-learn to load the Iris dataset and writes the data and corresponding target values into CSV files. The features and targets are saved in 'data/iris.csv' and 'data/iris_target.csv' respectively.

Definition in file importing_dataset.py.

5.1.2 Variable Documentation

5.1.2.1 iris

```
importing_dataset.iris = load_iris()
```

Definition at line 14 of file importing_dataset.py.

5.2 /Users/stanislav/Github/MachineLearning/ML-perceptron-learning-rule/importing_dataset.py

Go to the documentation of this file.

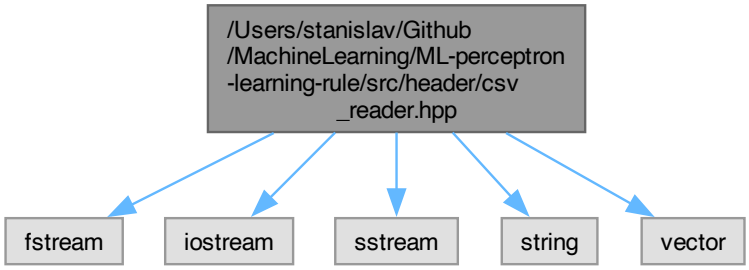
```
00001
00007
00008 from sklearn.datasets import load_iris
00009
00010
00013 if __name__ == '__main__':
00014     iris = load_iris()
00015     # Save the dataset (features and target) into a file.
00016     with open('data/iris.csv', 'w') as f:
00017         for i in range(len(iris.data)):
00018             f.write(','.join([str(x) for x in iris.data[i]]) + ',' + str(iris.target[i]) + '\n')
00019
00020     # Save the target values into a separate file.
00021     with open('data/iris_target.csv', 'w') as f:
00022         for i in range(len(iris.target)):
00023             f.write(str(iris.target[i]) + '\n')
```

5.3 /Users/stanislav/Github/MachineLearning/ML-perceptron-learning-rule/src/header/csv_reader.hpp File Reference

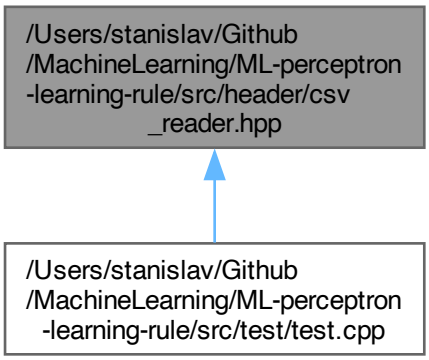
In this class the CSV reader is defined. This is for reading the iris data set.

```
#include <fstream>
#include <iostream>
#include <sstream>
#include <string>
#include <vector>
```

Include dependency graph for csv_reader.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- struct irisData

  A structure to hold the features and targets read from a CSV file. This is fdor the iris data set.

Functions

- std::vector< std::vector< std::string > > read_csv (const std::string &filename, char delimiter=',')

  Reads a CSV file and returns a vector of vectors.
- std::vector< int > get_targets (const std::vector< std::vector< std::string > > &data)

  Extracts the features from the data (column).
- std::vector< std::vector< float > > get_features (const std::vector< std::vector< std::string > > &data)

  Extracts the features from the data.
- irisData filter_data (const std::vector< std::vector< float > > &features, const std::vector< int > &targets, int target)

  Filters out data points with a specific target value.

5.3.1 Detailed Description

In this class the CSV reader is defined. This is for reading the iris data set.

Author

Stan Merlijn

Version

0.1

Date

2025-02-14

Copyright

Definition in file csv_reader.hpp.

5.3.2 Function Documentation

5.3.2.1 filter_data()

```
irisData filter_data (
            const std::vector< std::vector< float > > & features,
            const std::vector< int > & targets,
            int target)
```

Filters out data points with a specific target value.

This function takes a set of features and corresponding target values, and filters out the data points where the target value matches the specified target. The remaining data points are returned in a new irisData structure.

Parameters

features	A vector of vectors containing the feature data.
targets	A vector containing the target values corresponding to the feature data.
target	The target value to filter out from the data.

Returns

irisData A structure containing the filtered feature data and target values.

Definition at line 128 of file csv_reader.hpp.

5.3.2.2 get_features()

```
std::vector< std::vector< float > > get_features (
            const std::vector< std::vector< std::string > > & data)
```

Extracts the features from the data.

This function extracts the features from the data and returns a vector of vectors containing the features.

Parameters

data	A vector of vectors representing the rows in the CSV file.

Returns

A vector containing the features.

Definition at line 102 of file csv_reader.hpp.

5.3.2.3 get_targets()

```
std::vector< int > get_targets (
            const std::vector< std::vector< std::string > > & data)
```

Extracts the features from the data (column).

This function extracts the features from the data and returns a vector of vectors containing the features.

Parameters

data	A vector of vectors representing the rows in the CSV file.

Returns

A vector containing the features.

Definition at line 84 of file csv_reader.hpp.

5.3.2.4 read_csv()

```
std::vector< std::vector< std::string > > read_csv (
            const std::string & filename,
            char delimiter = ',')
```

Reads a CSV file and returns a vector of vectors.

This function reads a CSV file and returns a vector of vectors. Each inner vector represents a row in the CSV file. The function assumes that the CSV file is well-formed and does not contain any missing values.

Parameters

filename	The name of the CSV file to read.
delimiter	The delimiter used in the CSV file.

Returns

A vector of vectors representing the rows in the CSV file.

Definition at line 42 of file csv_reader.hpp.

5.4 csv_reader.hpp

Go to the documentation of this file.

```
00001
00011 #pragma once
00012 #include <fstream>
00013 #include <iostream>
00014 #include <sstream>
00015 #include <string>
00016 #include <vector>
00017
00018 struct irisData
00026 {
00027     std::vector<std::vector<float» features;
00028     std::vector<int> targets;
00029 };
00030
00042 std::vector<std::vector<std::string» read_csv(const std::string& filename, char delimiter=',')
00043 {
00044     // Create a vector to store the rows
00045     std::vector<std::vector<std::string» rows;
00046     std::ifstream file(filename);
00047
00048     // Check if the file is open
00049     if (!file.is_open()) {
00050         std::cerr « "Error: Could not open file " « filename « std::endl;
```

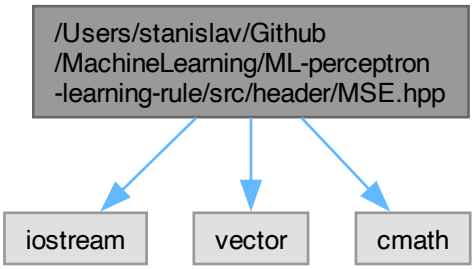
```
00051         return rows;
00052     }
00053
00054     // Read the file line by line
00055     std::string line;
00056     while (std::getline(file, line)) {
00057         std::stringstream ss(line);
00058         std::vector<std::string> cols;
00059         std::string col;
00060
00061         while (std::getline(ss, col, delimiter)) {
00062             cols.push_back(col);
00063         }
00064
00065         // Add the columns to the rows
00066         rows.push_back(cols);
00067     }
00068
00069     // Close the file
00070     file.close();
00071
00072     return rows;
00073 }
00074
00084 std::vector<int> get_targets(const std::vector<std::vector<std::string»& data)
00085 {
00086     std::vector<int> targets;
00087     for (const auto& row : data) {
00088         targets.push_back(std::stoi(row.back()));
00089     }
00090     return targets;
00091 }
00092
00102 std::vector<std::vector<float» get_features(const std::vector<std::vector<std::string»& data)
00103 {
00104     std::vector<std::vector<float» features;
00105     for (const auto& row : data) {
00106         std::vector<float> feature_row;
00107         // Skip the last column which contains the target
00108         for (int i = 0; i < row.size() - 1; i++) {
00109             feature_row.push_back(std::stof(row[i]));
00110         }
00111         features.push_back(feature_row);
00112     }
00113     return features;
00114 }
00115
00128 irisData filter_data(const std::vector<std::vector<float»& features, const std::vector<int>& targets,
      int target)
00129 {
00130     std::vector<std::vector<float» filtered_features;
00131     std::vector<int> filtered_targets;
00132     for (int i = 0; i < features.size(); i++) {
00133         if (targets[i] != target) {
00134             filtered_features.push_back(features[i]);
00135             filtered_targets.push_back(targets[i]);
00136         }
00137     }
00138     return irisData{filtered_features, filtered_targets};
00139 }
```

5.5 /Users/stanislav/Github/MachineLearning/ML-perceptron-learning-rule/src/header/MSE.hpp File Reference

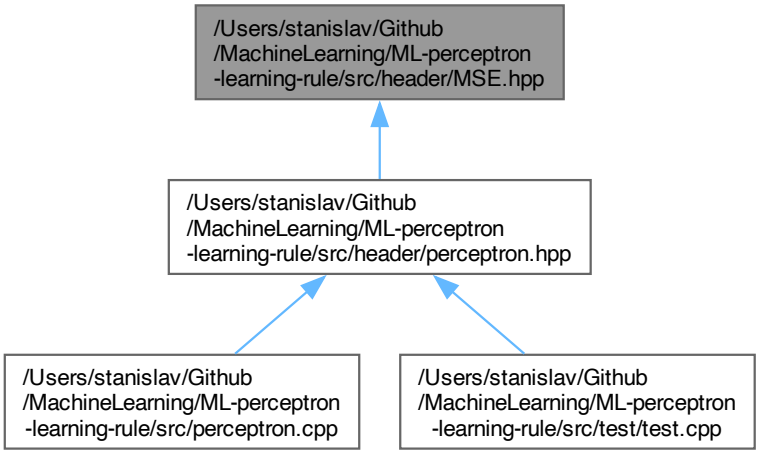
In this file the Mean Squared Error (MSE) function is defined.

```
#include <iostream>
#include <vector>
#include <cmath>
```

Include dependency graph for MSE.hpp:



This graph shows which files directly or indirectly include this file:



Functions

- double MSE (const std::vector< int > &targets, const std::vector< int > &predictions)

  Calculates the mean squared error between two vectors.

5.5.1 Detailed Description

In this file the Mean Squared Error (MSE) function is defined.

Author

Stan Merlijn

Version

0.1

Date

2025-02-14

Copyright

Definition in file MSE.hpp.

5.5.2 Function Documentation

5.5.2.1 MSE()

```
double MSE (
            const std::vector< int > & targets,
            const std::vector< int > & predictions)  [inline]
```

Calculates the mean squared error between two vectors.

This function computes the mean squared error (MSE) between the target values and the predicted values. The MSE is a measure of the average squared difference between the estimated values and the actual value.

Parameters

targets	A vector of target values.
predictions	A vector of predicted values.

Returns

The mean squared error between the targets and predictions. Returns -1 if the sizes of the input vectors do not match.

Definition at line 28 of file MSE.hpp.

5.6 MSE.hpp

Go to the documentation of this file.

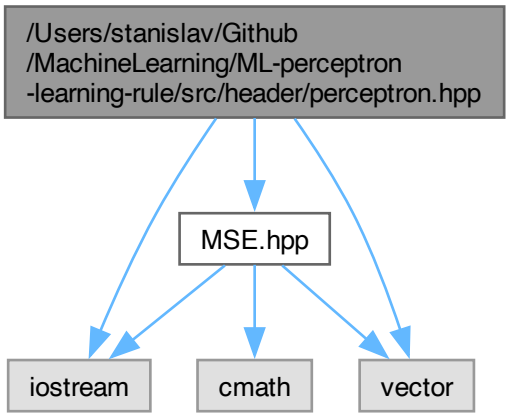
```
00001
00011 #pragma once
00012 #include <iostream>
00013 #include <vector>
00014 #include <cmath>
00015
00028 inline double MSE(const std::vector<int>& targets, const std::vector<int>& predictions)
00029 {
00030     // Ensure both arrays are the same size
00031     if (targets.size() != predictions.size()) return -1;
00032
00033     // Calculate the mean squared error
00034     double sum = 0;
00035     for (int i = 0; i < targets.size(); i++) {
00036         sum += pow(std::abs(targets[i] - predictions[i]), 2);
00037     }
00038     return sum / targets.size();
00039 }
```

5.7 /Users/stanislav/Github/MachineLearning/ML-perceptron-learning-rule/src/header/perceptron.hpp File Reference

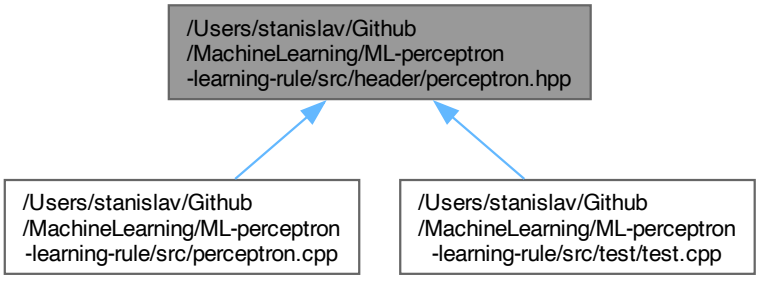
In this file the Perceptron class is declared.

```
#include "MSE.hpp"
#include <iostream>
#include <vector>
```

Include dependency graph for perceptron.hpp:



This graph shows which files directly or indirectly include this file:



Classes

- class Perceptron

  A simple perceptron model for binary classification.

5.7.1 Detailed Description

In this file the Perceptron class is declared.

Author

Stan Merlijn

Version

0.1

Date

2025-02-14

Copyright

Definition in file perceptron.hpp.

5.8 perceptron.hpp

Go to the documentation of this file.

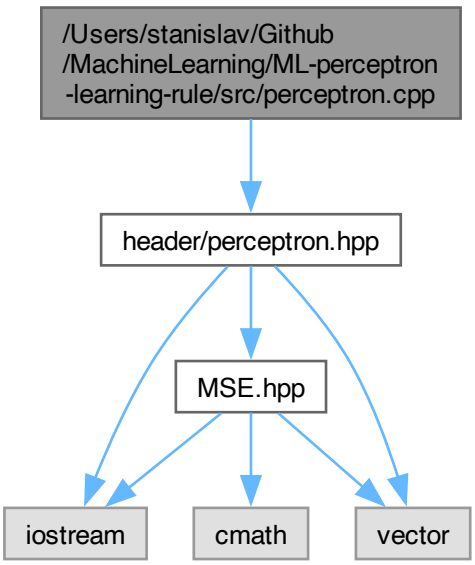
```
00001
00011 #pragma once
00012 #include "MSE.hpp"
00013 #include <iostream>
00014 #include <vector>
00015
00020 class Perceptron
00021 {
00022 public:
00029     Perceptron(std::vector<double> weights, double bias, double learningRate);
00030
00036     int predict(const std::vector<float>& x) const;
00037
00044     void update(const std::vector<std::vector<float>& inputs, const std::vector<int>& targets, int
      epochs);
00045
00052     double loss(const std::vector<std::vector<float>& inputs, const std::vector<int>& targets) const;
00057     void __str__(int verbose) const;
00058
00059 private:
00060     std::vector<double> weights;
00061     double bias;
00062     double learningRate;
00063 };
```

5.9 /Users/stanislav/Github/MachineLearning/ML-perceptron-learning-rule/src/perceptron.cpp File Reference

In this file the Perceptron class is implemented.

```
#include "header/perceptron.hpp"
```

Include dependency graph for perceptron.cpp:



5.9.1 Detailed Description

In this file the Perceptron class is implemented.

Author

Stan Merlijn

Version

0.1

Date

2025-02-14

Copyright

Copyright (c) 2025

Definition in file perceptron.cpp.

5.10 perceptron.cpp

Go to the documentation of this file.

```
00001
00011 #include "header/perceptron.hpp"
00012
00013 Perceptron::Perceptron(std::vector<double> weights, double bias, double learningRate)
00014     : weights(weights), bias(bias), learningRate(learningRate) {}
00015
00016 int Perceptron::predict(const std::vector<float>& inputs) const
00017 {
00018     // Dot prodcut for an array of size 2
00019     double dot_product = bias;
00020     for (int i = 0; i < weights.size(); i++) {
00021         dot_product += weights[i] * inputs[i];
00022     }
00023     // Threshold function
00024     return dot_product >= 0 ? 1 : 0;
00025 }
00026
00027 void Perceptron::update(const std::vector<std::vector<float>& inputs, const std::vector<int>& targets,
      int epochs)
00028 {
00029     // ensure both arrays are the same size
00030     if (inputs.size() != targets.size()) return;
00031
00032     // Train the perceptron
00033     for (int epoch = 0; epoch < epochs; epoch++) {
00034         // Loop through each input
00035         for (int i = 0; i < inputs.size(); i++) {
00036             // Get the prediction and error
00037             double pred = predict(inputs[i]);
00038             double error = targets[i] - pred;
00039
00040             // Update each weight based on the input value
00041             for (int j = 0; j < weights.size(); j++) {
00042                 weights[j] += learningRate * error * inputs[i][j];
00043             }
00044             // Update bias
00045             bias += learningRate * error;
00046         }
00047     }
00048 }
00049
00050 double Perceptron::loss(const std::vector<std::vector<float>& inputs, const std::vector<int>& targets)
      const
00051 {
00052     // Get the predictions for the inputs
00053     std::vector<int> predictions;
00054     for (int i = 0; i < inputs.size(); i++) {
00055         predictions.push_back(predict(inputs[i]));
00056     }
00057     // Calculate the mean squared error between the targets and predictions
00058     return MSE(targets, predictions);
00059 }
00060
00061 void Perceptron::__str__(int verbose) const
00062 {
00063     // Printing the weights
00064     std::cout « "weights for the perceptron:\n";
00065     for (int i = 0; i < weights.size(); i++) {
00066         std::cout « weights[i] « " ";
00067     }
00068     // Other info
00069     if (verbose >= 1) {
00070         std::cout « "\nbias = " « bias « "\n";
00071         std::cout « "Learning rate = " « learningRate « std::endl;
00072     }
00073 }
```

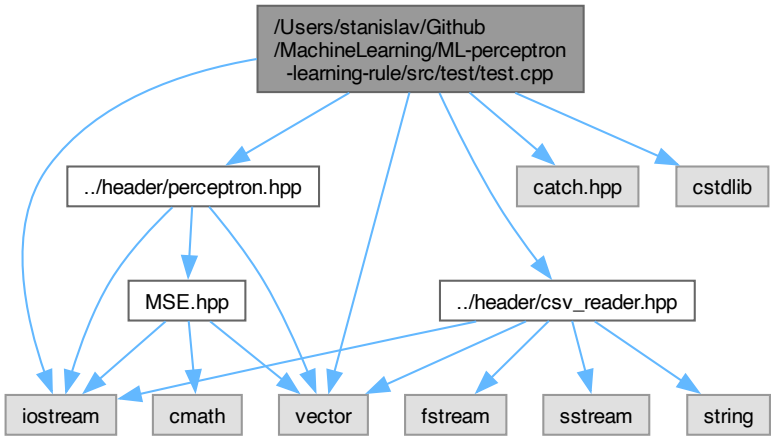
5.11 /Users/stanislav/Github/MachineLearning/ML-perceptron-learning-rule/src/test/test.cpp File Reference

In this file the tests for the Perceptron class are defined.

```
#include "../header/perceptron.hpp"
#include "../header/csv_reader.hpp"
```

```
#include "catch.hpp"
#include <iostream>
#include <vector>
#include <cstdlib>
```

Include dependency graph for test.cpp:



Macros

- #define CATCH_CONFIG_MAIN
- #define WEIGHTS std::vector<double>{0.5, 0.5}
- #define BIAS 0.5
- #define LEARNING_RATE 0.1

Functions

- TEST_CASE ("Perceptron AND gate", "[perceptron]")

  Test case for the AND gate using the Perceptron model.
- TEST_CASE ("Perceptron XOR gate", "[Perceptron XOR]")

  Test case for the XOR gate using the Perceptron model.
- TEST_CASE ("Iris data set - Perceptron Setosa en Versicolor", "[Perceptron Iris]")

  Test case for the Iris data set (Setosa vs Versicolor) using the Perceptron model.
- TEST_CASE ("Iris data set - Perceptron Versicolor en Virginica", "[Perceptron Iris]")

  Test case for the Iris data set (Versicolor vs Virginica) using the Perceptron model.

Variables

- std::vector< std::vector< std::string > > data = read_csv("../../data/iris.csv")
- std::vector< int > targets = get_targets(data)
- std::vector< std::vector< float > > features = get_features(data)

5.11.1 Detailed Description

In this file the tests for the Perceptron class are defined.

Unit tests for the Perceptron, PerceptronLayer and PerceptronNetwork classes.

Author

Stan Merlijn

Version

0.1

Date

2025-02-14

Copyright

This file contains a series of test cases to verify the functionality of the Perceptron and PerceptronLayer classes. The tests include training and prediction for various logic gates.

Test Cases:

- Perceptron for AND Gate: Tests the perceptron's ability to learn the AND gate.
- Perceptron for XOR Gate: Tests the perceptron's ability to learn the XOR gate.
- Perceptron for Iris Data Set: Tests the perceptron's ability to learn the Setosa and Versicolor classes.
- Perceptron for Iris Data Set: Tests the perceptron's ability to learn the Versicolor and Virginica classes.

Note

The tests use the Catch2 framework for unit testing.

Definition in file test.cpp.

5.11.2 Macro Definition Documentation

5.11.2.1 BIAS

```
#define BIAS 0.5
```

Default bias for the perceptron.

Definition at line 39 of file test.cpp.

5.11.2.2 CATCH_CONFIG_MAIN

```
#define CATCH_CONFIG_MAIN
```

Definition at line 14 of file test.cpp.

5.11.2.3 LEARNING_RATE

```
#define LEARNING_RATE 0.1
```

Default learning rate for the perceptron.

Definition at line 40 of file test.cpp.

5.11.2.4 WEIGHTS

```
#define WEIGHTS std::vector<double>{0.5, 0.5}
```

Default weights for the perceptron.

Definition at line 38 of file test.cpp.

5.11.3 Function Documentation

5.11.3.1 TEST_CASE() [1/4]

```
TEST_CASE (
            "Iris data set - Perceptron Setosa en Versicolor" ,
            "" [Perceptron Iris])
```

Test case for the Iris data set (Setosa vs Versicolor) using the Perceptron model.

This test trains a perceptron on the subset of the Iris data set that contains only the Setosa and Versicolor classes. The perceptron is expected to correctly separate the two classes with a loss of 0. The final weights and loss are printed.

Definition at line 145 of file test.cpp.

5.11.3.2 TEST_CASE() [2/4]

```
TEST_CASE (
            "Iris data set - Perceptron Versicolor en Virginica" ,
            "" [Perceptron Iris])
```

Test case for the Iris data set (Versicolor vs Virginica) using the Perceptron model.

This test trains a perceptron on the subset of the Iris data set that contains only the Versicolor and Virginica classes. In this scenario, the perceptron cannot correctly separate the two classes, hence a non-zero loss is expected. The test prints the final weights and computed loss after training.

Definition at line 207 of file test.cpp.

5.11.3.3 TEST_CASE() [3/4]

```
TEST_CASE (
            "Perceptron AND gate" ,
            "" [perceptron])
```

Test case for the AND gate using the Perceptron model.

This test case trains a perceptron on the AND gate truth table. The perceptron is expected to correctly learn the AND behavior:

- For inputs {0, 0}, {0, 1}, and {1, 0} the output should be 0.
- For input {1, 1} the output should be 1. The test prints the final weights and computed loss after training.

Definition at line 58 of file test.cpp.

5.11.3.4 TEST_CASE() [4/4]

```
TEST_CASE (
            "Perceptron XOR gate" ,
            "" [Perceptron XOR])
```

Test case for the XOR gate using the Perceptron model.

This test case trains a perceptron on the XOR gate truth table. Since the XOR function is non-linearly separable, a single perceptron cannot correctly learn the XOR behavior. Therefore, the expected behavior is:

- The perceptron incorrectly predicts the output for {0, 0} (i.e. output is not 0).
- The perceptron correctly predicts the output for {0, 1} (i.e. output is 1).
- The perceptron incorrectly predicts the output for {1, 0} (i.e. output is not 1).
- The perceptron correctly predicts the output for {1, 1} (i.e. output is 0).

The test prints the final weights and computed loss after training.

Definition at line 94 of file test.cpp.

5.11.4 Variable Documentation

5.11.4.1 data

```
std::vector<std::vector<std::string> > data = read_csv("../../data/iris.csv")
```

Definition at line 43 of file test.cpp.

5.11.4.2 features

```
std::vector<std::vector<float> > features = get_features(data)
```

Definition at line 47 of file test.cpp.

5.11.4.3 targets

```
std::vector<int> targets = get_targets(data)
```

Definition at line 46 of file test.cpp.

5.12 test.cpp

Go to the documentation of this file.

```
00001
00011 #include "../header/perceptron.hpp"
00012 #include "../header/csv_reader.hpp"
00013
00014 #define CATCH_CONFIG_MAIN
00015 #include "catch.hpp"
00016
00017 #include <iostream>
00018 #include <vector>
00019 #include <cstdlib>   // For rand()
00020
00036
00037 // Define the default inputs
00038 #define WEIGHTS std::vector<double>{0.5, 0.5}
00039 #define BIAS 0.5
00040 #define LEARNING_RATE 0.1
00041
00042 // Read the iris data set
00043 std::vector<std::vector<std::string» data = read_csv("../../data/iris.csv");
00044
00045 // Extract the features and targets
00046 std::vector<int>                targets  = get_targets(data);
00047 std::vector<std::vector<float» features = get_features(data);
00048
00058 TEST_CASE("Perceptron AND gate", "[perceptron]")
00059 {
00060     Perceptron andGate(WEIGHTS, BIAS, LEARNING_RATE);
00061     std::vector<std::vector<float» inputs = {{0, 0}, {0, 1}, {1, 0}, {1, 1}};
00062     std::vector<int> targets = {0, 0, 0, 1};
00063
00064     // Train the perceptron
00065     andGate.update(inputs, targets, 100);
00066
00067     REQUIRE(andGate.predict({0, 0}) == 0);
00068     REQUIRE(andGate.predict({0, 1}) == 0);
00069     REQUIRE(andGate.predict({1, 0}) == 0);
00070     REQUIRE(andGate.predict({1, 1}) == 1);
00071
00072     // Print the weights
00073     std::cout « "Training for the AND gate:\n";
00074     andGate.__str__(1);
00075
00076     // Calculate the loss
00077     double loss = andGate.loss(inputs, targets);
00078     std::cout « "Loss: " « loss « "\n" « std::endl;
00079 }
00080
00094 TEST_CASE("Perceptron XOR gate", "[Perceptron XOR]")
00095 {
00096     Perceptron xorGate(WEIGHTS, BIAS, LEARNING_RATE);
00097     std::vector<std::vector<float» inputs = {{0, 0}, {0, 1}, {1, 0}, {1, 1}};
00098     std::vector<int> targets = {0, 1, 1, 0};
00099
00100     // Train the perceptron
00101     xorGate.update(inputs, targets, 100);
00102
00103     REQUIRE_FALSE(xorGate.predict({0, 0}) == 0); // This should fail for XOR
00104     REQUIRE(xorGate.predict({0, 1}) == 1); // This should pass
00105     REQUIRE_FALSE(xorGate.predict({1, 0}) == 1); // This should fail for XOR
00106     REQUIRE(xorGate.predict({1, 1}) == 0); // This should pass
00107
00108     // Print the weights
00109     std::cout « "Training for the XOR gate:\n";
00110     xorGate.__str__(1);
00111
00112     // Calculate the loss
00113     double loss = xorGate.loss(inputs, targets);
00114     std::cout « "Loss: " « loss « "\n" « std::endl;
00115
```

```
00116     // FAILED:
00117     //   REQUIRE( xorGate.predict({0, 0}) == 0 )
00118     // with expansion:
00119     //   1 == 0
00120
00121     // FAILED:
00122     //   REQUIRE( xorGate.predict({1, 0}) == 1 )
00123     // with expansion:
00124     //   0 == 1
00125
00126     // weights:
00127     // -0.1 2.77556e-17
00128     // bias = 2.77556e-17
00129     // Learning rate = 0.1
00130     // Loss: 0.5
00131
00132     // A XOR gate is a linearly inseparable function, which means that a single perceptron
00133     // cannot learn the weights to create a XOR gate.
00134 }
00135
00136
00137
00145 TEST_CASE("Iris data set - Perceptron Setosa en Versicolor", "[Perceptron Iris]")
00146 {
00147     irisData iris01 = filter_data(features, targets, 2);
00148
00149     // Student ID for seeding
00150     std::srand(1863967);
00151
00152     // Generate random weights, bias, and learning rate
00153     std::vector<double> weights;
00154     double bias = double(std::rand()) / RAND_MAX * 0.5;
00155     double learningRate = double(std::rand()) / RAND_MAX * 0.5;
00156
00157     // Generate random weights
00158     for (int i = 0; i < iris01.features[0].size(); i++)
00159     {
00160         weights.push_back((double)std::rand() / RAND_MAX - 0.5);
00161     }
00162
00163     // Create a perceptron object
00164     Perceptron irisPerceptron(weights, BIAS, LEARNING_RATE);
00165
00166     // Train the perceptron
00167     irisPerceptron.update(iris01.features, iris01.targets, 1000);
00168
00169     // Print the weights and loss after training
00170     double loss = irisPerceptron.loss(iris01.features, iris01.targets);
00171     std::cout « "Training the perceptron on the Setosa and Versicolor" « std::endl;
00172     irisPerceptron.__str__(1);
00173     std::cout « "Loss: " « loss « "\n" « std::endl;
00174
00175     std::vector<int> predictions;
00176     std::vector<int> targets;
00177
00178     for (int i = 0; i < iris01.features.size(); i++)
00179     {
00180         int prediction = irisPerceptron.predict(iris01.features[i]);
00181         int target = iris01.targets[i];
00182         predictions.push_back(prediction);
00183         targets.push_back(target);
00184     }
00185
00186     CHECK(predictions == targets);
00187
00188     // Training the perceptron on the iris data set
00189     // ------------------------------------------------
00190     // Training the perceptron on the Setosa and Versicolor
00191     // weights:
00192     // -0.244404 -0.199549 0.569217 0.417662
00193     // bias = 0.4
00194     // Learning rate = 0.1
00195     // Loss: 0
00196     // The loss is 0 because the perceptron is able to separate the two classes
00197 }
00198
00207 TEST_CASE("Iris data set - Perceptron Versicolor en Virginica", "[Perceptron Iris]")
00208 {
00209     irisData iris12 = filter_data(features, targets, 0);
00210
00211     // Student ID for seeding
00212     std::srand(1863967);
00213
00214     // Generate random weights, bias, and learning rate
00215     std::vector<double> weights;
00216     double bias = double(std::rand()) / RAND_MAX * 0.5;
00217     double learningRate = double(std::rand()) / RAND_MAX * 0.5;
```

```
00218
00219     // Generate random weights
00220     for (int i = 0; i < iris12.features[0].size(); i++)
00221     {
00222         weights.push_back((double)std::rand() / RAND_MAX - 0.5);
00223     }
00224
00225     // Create a perceptron object
00226     Perceptron irisPerceptron(weights, BIAS, LEARNING_RATE);
00227
00228     // Train the perceptron
00229     irisPerceptron.update(iris12.features, iris12.targets, 1000);
00230
00231     // Print the weights and loss after training
00232     double loss = irisPerceptron.loss(iris12.features, iris12.targets);
00233     std::cout « "Training the perceptron on the Versicolor and Virginica" « std::endl;
00234     irisPerceptron.__str__(1);
00235     std::cout « "Loss: " « loss « "\n" « std::endl;
00236
00237     std::vector<int> predictions;
00238     std::vector<int> targets;
00239
00240     for (int i = 0; i < iris12.features.size(); i++)
00241     {
00242         int prediction = irisPerceptron.predict(iris12.features[i]);
00243         int target = iris12.targets[i];
00244         predictions.push_back(prediction);
00245         targets.push_back(target);
00246     }
00247
00248     CHECK(predictions == targets);
00249
00250     // Training the perceptron on the Versicolor and Virginica
00251     // weights:
00252     // 32939.9 14870.2 27760 10130.2
00253     // bias = 5000.5
00254     // Learning rate = 0.1
00255     // Loss: 0.5
00256     // The loss is 0.5 because the perceptron is not able to separate the two classes
00257 }
```

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