Pistachio Classification Using a Multilayer Perceptron

Abstract

Pistachios are seeds of the Pistacia Vera L. tree. They are consumed as food globally. In pistachio production, different varieties are often mixed together in the course of harvesting, transportation, handling, storage etc. This adds the cost of having human operators to seperate them into their respective varities. Machine learning can be used to reduce costs related to errors made in this process. In this project, a multilayer perceptron was trained using gradient descent and backpropagation to classify pistachio samples. A dataset of of 2148 samples, 1232 of Kirmizi and 916 of Siirt pistachios was used. These samples are composed of 28 features extracted from pistachio images. Multiple tests were done on this perceptron and the best performance obtained was 92.79% after 10000 training iterations

Contents

1 Introduction

Pistachios are seeds of the pistachio tree widely consumed as food. Pistachio nuts are often mixed together in the course of harvesting, transportation, storage, etc. Therefore, human operators are needed to manually seperate them into their respective types. Pistachios are expensive argicultural products and this only adds to their cost. Furthermore manual handling and seperation introduces its own set of problems and may be prone to errors. The aim of this project is to develop and test the efficacy of a multilayer perceptron in classifying pistachio samples. In the following sections, I will give some background on pistachios and multilayer perceptrons, then I will review some previous literature related to the project and conclude with a discussion on the project itself.

2 Background

2.1 Pistachios

The Pistachio (Pistacia vera L.) is an ancient tree of the Anacardiaceae family. It is native to the Middle East and Central Asia but is today grown in many parts of the world including the United States and Turkey. It produces seeds widely consumed as food all over the world. Archaeological records show that they were consumed in Turkey as early as 7,000 B.C. The fruit of this tree is surrounded by a hard shell which contains the seeds themselves which constitute the edible portion. It has been selected by humans to split open upon ripening. They are of a light green color, fleshy and have a distinctive flavor (Padulosi et al., 2008).

Data for 2021 show that the United States and Turkey are two of the leading producers of pistachios (Saglam and Cetin, 2021). Kirmizi and Siirt are some of the most popular pistachio varieties in Turkey (Singh et al., 2022).

Pistachios are often sold in their shells directly which makes it neccessary to inspect and seperate them into their types (Omid et al., 2009). Being expensive argicultural products automated classification of pistachios could reduce costs incurred from the errors of human operators (Singh et al., 2022).

2.2 Multilayer Perceptrons

Deep feedforward networks are the quintessential deep learning models (Goodfellow et al., 2016). The goal of these networks is to learn the relationship between the input examples and the outputs. A multilayer perceptron is a feedforward artificial neural network with at least three layers: an input, a hidden and an output

layer. The layers are composed of units connected to units of the succeeding layer. These connections are associated with certain weights. Each unit computes an output by applying a nonlinear activation function to the weighted sum of its inputs. The output of the final layer is the output of the model (Russell and Norvig, 2021).

Any composition of linear units produces a linear output but with nonlinear activation functions a sufficiently large network can represent arbitrary nonlinear relationships. Historically the logistic sigmoid and hyperbolic tangent functions were the standard functions used for this purpose. But today their use is discouraged in favour of the rectified linear unit. This function is zero for half its domain and linear for the rest. Its derivative is one everywhere the unit is active and its second derivative is zero almost everywhere. This makes the direction of the gradient more useful for learning (Goodfellow et al., 2016).

The multilayer perceptron network may also be considered as a composition of functions that represent the layers of the network with the weights representing the parameters of the functions (Goodfellow et al., 2016). The error of the output is calculated using a cost function and the goal of learning is to minimise the cost function by altering the weights. This is most popularly done using any variant of gradient descent. Gradient Descent is a method of finding a local minimum of the cost function by altering the parameters of the model in the opposide direction of the gradient of the cost function. The amount by which the parameters are altered at each step is determined by a learning rate (Ruder, 2016).

Numerically evaluating the analytical expression for the gradient directly can be computationally expensive as it involves many duplicate calculations (Goodfellow et al., 2016). An algorithm called backpropagation can be used to compute this gradient efficiently. The weights of the network only affect the total loss through their effect on the next layer. Backpropagation exploits this property to recursively compute the gradient of a layer using the gradient of the next layer. Since the gradient of a layer is computed directly with respect to the total loss, the intermediate duplicate computations of the hidden layers are avoided.

3 Related Work

Singh et al., 2022 classified Kirmizi and Siirt pistachios using convolutional neural networks. A dataset of 2148 images, 1232 of the Kirmizi type and 916 of the Siirt type was used. 80% of the dataset was used for training and the rest for testing. They used three pre-trained convolutional neural networks: AlexNet, VGG16 and VGG19. They report results of 94.42%, 98.84%, and 98.14%, respectively. This

study demonstrates that pistachio types can be successfully classified using deep learning systems.

Mahdavi-Jafari et al. introduced a system for classifying pistachio nuts using a multilayer perceptron based on acoustic signals produced by pistachio collisions against a steel plate. To this end, they developed an acoustic box fitted with a microphone and a digital signal processing card to receive and process the sounds generated on impact. They reduced the dimensionality of the data using a window and further applied the Fast Fourier Transform, the Discrete Cosine Transform, and the Discrete Wavelet Transform, to select the essential features of the data. They report a high performance rate of 99.89% with a dataset of three sets of fifty nuts.

Omid et al. developed a similar system for classifying pistachio nut varieties using the sound of impact of the pistachios against a steel plate. They used four varieties of 800 pistachios, 400 split-shelled and 400 close-shelled. They slid the nuts down a chute inclined at a 60 degree angle and recorded their impacts on a steel plate. They used Fast Fourier Transform for feature generation and Principal Component Analysis for dimensionality reduction using which they were able to reduce the number of features by 98%. They used this data to train a multilayer perceptron with topology: 40-12-4. Using this network they were able to achieve an accurate separation rate of 97.5 percent.

4 Project

4.1 Overview

For this project, I have written and trained a multilayer perceptron to classify Kirmizi and Siirt pistachios. Below, after a brief discussion on the dataset used, I will go into details about the model and conclude with a discussion on the results.

4.2 Dataset

The dataset consists of 2148 samples, 1232 of Kirmizi and 916 of Siirt pistachios. A sample is composed of 28 features extracted from images of those pistachios. The dataset was normalized before training to values between 0 and 1.

4.3 Model

The number of layers and their sizes are general in the program and can be adjusted. After tuning the hyperparameters, a 2-layer topology was chosen, with

2 units in the hidden layer and 1 unit in the output layer. The logistic sigmoid function was used as the activation function for the entire network.

4.4 Learning

The weights are initialized randomly and learned using Gradient Descent and Backpropagation. The loss function used is $\frac{1}{2}\sum_{i=1}^{n}(o_i - t_i)^2$.

4.5 Results

Multiple tests were done with the dataset shuffled randomly. The dataset was split into 80% training and 20% test sets. With a large enough number of iterations, the performance was observed to be approximately 90% reliably, with a best performance of 92.79% after 10000 iterations.

5 Conclusion

Machine adided pistachio classification can potentially yield significant economic gains in the industry. The results of this project and the literature reviewed show promise in the use of multilayer perceptrons or other kinds of neural networks for this task.

References

[1] Giuseppe Bonifazi et al. "Contaminant detection in pistachio nuts by different classification methods applied to short-wave infrared hyperspectral images". In: *Food Control* 130 (Dec. 2021), p. 108202. DOI: 10.1016/j.foodcont.2021.108202.

[2] I. Goodfellow, Y. Bengio, and A. Courville. *Deep Learning*. Adaptive Computation and Machine Learning series. MIT Press, 2016. ISBN: 9780262035613.

[3] Somaieh Mahdavi-Jafari, Hojjat Salehinejad, and Siamak Talebi. "A Pistachio Nuts Classification Technique: An ANN Based Signal Processing Scheme". In: *2008 International Conference on Computational Intelligence for Modelling Control and Automation* (2008), pp. 447–451.

[4] Mahmoud Omid, Asghar Mahmoudi, and Mohammad H. Omid. "An intelligent system for sorting pistachio nut varieties". In: *Expert Systems with Applications* 36.9 (2009), pp. 11528–11535. ISSN: 0957-4174.

[5] A. Padulosi S.; Hadj-Hassan. "Towards a comprehensive documentation and use of Pistacia genetic diversity in Central and West Asia, North Africa and Europe." In: (2001).

[6] S. Ruder. “An overview of gradient descent optimization algorithms”. In: (2016).

[7] S.J. Russell and P. Norvig. *Artificial Intelligence: A Modern Approach*. Pearson series in artificial intelligence. Pearson, 2021. ISBN: 9781292401133.

[8] Cevdet Saglam and Necati Cetin. “Prediction of Pistachio (Pistacia vera L.) Mass Based on Shape and Size Attributes by Using Machine Learning Algorithms”. In: *Food Analytical Methods* 15.3 (Nov. 2021), pp. 739–750. DOI: 10.1007/s12161-021-02154-6.

[9] Dilbag Singh et al. “Classification and Analysis of Pistachio Species with Pre-Trained Deep Learning Models”. In: *Electronics* 11.7 (2022). ISSN: 2079-9292. DOI: 10.3390/electronics11070981.

[10] Dilbag Singh et al. “Classification and Analysis of Pistachio Species with Pre-Trained Deep Learning Models”. In: *Electronics* 11.7 (2022).