

ANN for Mushroom Prediction

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Abstract: *Predication is an application of Artificial Neural Network (ANN). It is a supervised learning due to predefined input and output attributes. Multi-Layer ANN model is used for training, validating, and testing of the data set. In this paper, Multi-Layer ANN model was used to train and test the mushroom dataset to predict whether mushroom is edible or poisonous. The Mushrooms dataset was prepared for training, 8124 instances were used for the training. JNN tool was used for training and validating the dataset. The most important attributes of the dataset were identified, and the accuracy of the predication of whether Mushroom is edible or Poisonous was 100%.*

Keywords: artificial neural network, JNN, poisonous, mushroom, edible

1. INTRODUCTION

The standard "mushroom" is the cultivated white button mushroom, *Agaricus bisporus*; therefore the word "mushroom" is usually applied to those fungi (Basidiomycota, Agaricomycetes) that have a stem (stipe), a cap (pileus), and gills (lamellae, sing. lamella) on the bottom of the cap. "Mushroom" as well describes a variation of other gilled fungi, with or without stems; hence the term is used to describe the fleshy fruiting bodies of some Ascomycota. These gills produce microscopic spores that aid the fungus spread across the ground [1].

Mushrooms are used widely in cooking, in various cuisines (notably Chinese, Korean, European, and Japanese). Though neither meat nor vegetable, mushrooms are acknowledged as the "meat" of the vegetable world. Most mushrooms sold in supermarkets have been commercially produced on mushroom farms. The most common of these, *Agaricus bisporus*, is well-thought-out to be safe for utmost people to eat since it is grown in controlled, sterilized surroundings. Numerous varieties of *A. bisporus* are grown commercially, as well as whites, crimini, and portobello. Other cultivated species existing at many grocers include *Hericium erinaceus*, shiitake, maitake (hen-of-the-woods), *Pleurotus*, and enoki. Recently, increasing wealth in developing countries has directed to a substantial growth in attention in mushroom cultivation, which is now seen as a possibly significant economic activity for small farmers. The main edible mushroom producer is China [2].

The country produces about half of all cultivated mushrooms, and around 2.7 kg of mushrooms are consumed per person per year by over a billion people. In 2014, Poland was the world's largest mushroom exporter, reporting an estimated 194,000 tons annually. Distinguishing edible from poisonous mushroom species needs meticulous care to detail; there is no single trait by which all toxic mushrooms can be recognized, nor one by which all edible mushrooms can be recognized. People who gather mushrooms for eating are known as mycophagists and the act of gathering them for such is known as mushroom hunting, or simply "mushrooming". Even edible mushrooms may yield allergic reactions in susceptible individuals, from a mild asthmatic response to severe anaphylactic shock. Even the cultivated *A. bisporus* comprises small amounts of hydrazines, the most copious of which is agaritine (a mycotoxin and carcinogen) [3].

Nevertheless, the hydrazines are demolished by reasonable heat when cooking. A number of species of mushrooms are poisonous; even though some resemble sure edible species, consuming them could be deadly. Eating mushrooms collected in the wild is risky and should only be undertaken by individuals knowledgeable in mushroom recognition. Mutual best practice is for wild mushroom pickers to focus on gathering a small number of visually distinct, edible mushroom species that cannot be simply confused with poisonous varieties [4].

2. ARTIFICIAL NEURAL NETWORKS

Artificial neural networks (ANNs) are parallel computational models comprised of densely interconnected, adaptive processing units, characterized by an inherent propensity for learning from experience and also discovering new knowledge. Due to their excellent capability of self-learning and self-adapting, they have been extensively studied and have been successfully utilized to tackle difficult real-world problems and are often found to be more efficient and more accurate than other classification techniques. Classification with a neural network takes place in two distinct phases. First, the network is trained on a set of paired data to determine the input-output mapping [5].

The weights of the connections between neurons are then fixed and the network is used to determine the classifications of a new set of data [6]. Although many different models of ANNs have been proposed, the feedforward neural networks (FNNs) are the most common and widely used in a variety of applications [7].

Mathematically, the problem of training a FNN can be formulated as the minimization of an error function E ; that is to find a minimizer [14-16] where E is the batch error measure defined by the sum of square differences over all examples of the training set, namely where y_j , p is the actual output of the j -th neuron that belongs to the L -th (output) layer, N_L is the number of neurons of the output layer, t_j , p is the desired response at the j -th neuron of the output layer at the input pattern p and P represents the total number of patterns used in the training set. A traditional way to solve this problem is by an iterative gradient-based training algorithm which generates a sequence of weights $\{w\}$ starting from an initial guess. The iterative formula where k is the current iteration usually called epoch, $\eta > 0$ is the learning rate and d_k is a descent search direction [8].

Since the appearance of backpropagation a variety of approaches that use second order derivative related information was suggested for improving the efficiency of the minimization error process [9]. Here, we have utilized three well-known and widely used classical methods, namely the Broyden-Fletcher-Goldfarb-Shanno (BFGS), the Levenberg-Marquardt (LM) and the Resilient Backpropagation (Rprop). Moreover, we have also used a new efficient conjugate gradient algorithm, the modified spectral Perry (MSP). Due to space limitations, we are not in a position to briefly describe here the above methods. The interested reader is referred to [10-12].

The Biological Model (Neural Networks):

- Neural networks as a computing model possess the following properties [13-16]:
 - Operate in parallel Computing elements (neurons) work in parallel as opposed to the sequential action of Turing machines.
 - Hierarchical Multilayered Structure Information is transmitted not only to immediate neighbors, but also to more distant units, as opposed to CA.
 - No Program is handed over to the hardware The free parameters of the network have to be found adaptively - as opposed to conventional computers (which require pre-programmed algorithms to execute).
- Structure of the Neuron

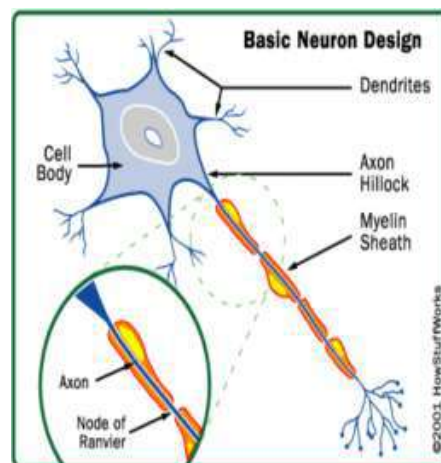


Figure 1: Cell

The cell body (soma) : "Processing" occurs here [27-30]:

- Dendrites: Protrude from soma. They conduct signals to the cell body
- Axon Hillock: Extends from cell body - initial portion of the axon.
- Axon: A long fiber - generally splits into smaller branches.
- Synapse: The axon-dendrite (axon-soma; axon-axon) contact between an endbulb and the cell it impinges upon is called a synapse [66-70]. (End bulbs can be seen at the bottom right corner of the above image.)

3. STUDY OBJECTIVES

The objectives of this study are:

- to determine some suitable factors that affect predicting the Validity of Mushrooms
- to transform these factors into forms suitable for an adaptive system coding
- to model an Artificial neural network that can be used to predict the Validity of Mushrooms based some given input data for a given Mushrooms.

4. Literature Review

Artificial Neural Networks have been used many fields. In Education such as: Predicting Student Performance in the Faculty of Engineering and Information Technology using ANN, Prediction of the Academic Warning of Students in the Faculty of Engineering and Information Technology in Al-Azhar University-Gaza using ANN, Arabic Text Summarization Using AraBERT Model Using Extractive Text Summarization Approach[6].

In the field of Health such as: Parkinson's Disease Prediction, Classification Prediction of SBRCTs Cancers Using ANN [7], Predicting Medical Expenses Using ANN[8], Predicting Antibiotic Susceptibility Using Artificial Neural Network[10], Predicting Liver Patients using Artificial Neural Network[9], Blood Donation Prediction using Artificial Neural Network[11], Predicting DNA Lung Cancer using Artificial Neural Network[12], Diagnosis of Hepatitis Virus Using Artificial Neural Network[13], COVID-19 Detection using Artificial Intelligence[14].

In the field of Agriculture: Plant Seedlings Classification Using Deep Learning [14], Prediction of Whether Mushroom is Edible or Poisonous Using Back-propagation Neural Network[15], Analyzing Types of Cherry Using Deep Learning[15], Banana Classification Using Deep Learning[13], Mango Classification Using Deep Learning[16], Type of Grapefruit Classification Using Deep Learning[7], Grape Type Classification Using Deep Learning[30], Classifying Nuts Types Using Convolutional Neural Network[17], Potato Classification Using Deep Learning[18], Age and Gender Prediction and Validation Through Single User Images Using CNN[5].

In other fields such as : Predicting Software Analysis Process Risks Using Linear Stepwise Discriminant Analysis: Statistical Methods [13], Predicting Overall Car Performance Using Artificial Neural Network [8], Glass Classification Using Artificial Neural Network [9], Tic-Tac-Toe Learning Using Artificial Neural Networks[15], Energy Efficiency Predicting using Artificial Neural Network[14], Predicting Titanic Survivors using Artificial Neural Network[12], Classification of Software Risks with Discriminant Analysis Techniques in Software planning Development Process[13], Handwritten Signature Verification using Deep Learning[12], Email Classification Using Artificial Neural Network[14], Predicting Temperature and Humidity in the Surrounding Environment Using Artificial Neural Network[15], English Alphabet Prediction Using Artificial Neural Networks[18].

5. Methodology

After getting the Mushroom dataset from “the Center for Machine Learning and Intelligent Systems, University of California, Irvine”[19], we identified the input variables, output variables, upload the dataset, divided it to training and validating sets, determined the proper hidden layers. Then we trained and validated the sets to get the best accuracy.

5.1 The Input Variables

The input variables selected are those which can easily be obtained from Mushroom Database. The input variables are: cap-shape, cap-surface, cap-color, bruises?, odor, gillattachment, gill-spacing, gill-size, gill-color, stalk-shape, stalk-root, stalk-surface-above-ring, stalk-surface-belowring, stalk-color-above-ring, stalk-color-below-ring, veiltype, veil-color, ring-number, ring-type, spore-print-color, population, Habitat. These factors were transformed into a format suitable for neural network analysis. The domain of the input variables used in this study shown in Table1.

Table1: Input variables

#	Input Variable	Domain
1	cap-shape	bell=b , conical=c , convex=x , flat=f , knobbed=k , sunken=s
2	cap-surface:	fibrous=f , grooves=g , scaly=y , smooth=s
3	cap-color:	brown=n , buff=b , cinnamon=c , gray=g , green=r , pink=p , purple=u , red=e white=w , yellow=y
4	bruises?:	bruises=t ,no=f

5	odor:	almond=a ,anise=l , creosote=c , fishy=y , foul=f , musty=m , none=n , pungent=p , spicy=s
6	gill-attachment:	attached=a ,descending=d ,free=f ,notched=n
7	gill-spacing	close=c ,crowded=w ,distant=d
8	gill-size:	broad=b ,narrow=n
9	gill-color:	black=k , brown=n , buff=b , chocolate=h , gray=g , green=r , orange=o , pink=p , purple=u , red=e , white=w , yellow=y
10	stalk-shape:	enlarging=e , tapering=t
11	stalk-root:	bulbous=b ,club=c , cup=u , equal=e , rhizomorphs=z , rooted=r , missing=?
12	stalk-surface-above-ring:	ibrous=f , scaly=y ,silky=k , smooth=s
13	stalk-surface-below-ring:	ibrous=f , scaly=y , silky=k , smooth=s
14	stalk-color-above-ring:	brown=n , buff=b , cinnamon=c , gray=g , orange=o , pink=p , red=e , white=w , yellow=y
15	stalk-color-below-ring:	brown=n ,buff=b ,cinnamon=c ,gray=g ,orange=o ,pink=p ,red=e ,white=w ,yellow=y
16	veil-type:	partial=p , universal=u
17	veil-color:	brown=n , orange=o , white=w , yellow=y
18	ring-number:	none=n , one=o , two=t
19	ring-type:	cobwebby=c , evanescent=e , flaring=f , large=l , none=n , pendant=p , sheathing=s , zone=z
20	spore-print-color:	black=k , brown=n , buff=b , chocolate=h , green=r , orange=o , purple=u , white=w , yellow=y
21	population:	abundant=a , clustered=c , numerous=n , scattered=s , several=v , solitary=y
22	Habitat :	grasses=g , leaves=l , meadows=m , paths=p , urban=u , waste=w , woods=d

5.2 Output variable

The output variable is whether the mushroom edible or poisonous.

5.3 Neural Network

Topologies After the data classification, the neural network topology was built based on the Multilayer Perceptron with one input layer, two hidden layers (3x1) and one output layer as shown in Figure 5.

5.4 Evaluation of the study

First of all, for the evaluation our study, we used a sample of 8124 mushrooms representing edible and non-edible mushrooms. Most of the mushrooms are Poisonous in order to examine whether the Mushroom is edible or not edible, we develop a model able to differentiate between edible and poisonous mushrooms. Our model uses a neural network with one input layer, two hidden layers and one output layer. As input data for predicting the Validity of Mushrooms we used attribute as shown in Figure 2.

	class	cap-shape	cap-surface	cap-color	stems	odor	gill-attach	gill-spec	gill-size	gill-color	stalk-shape	stalk-root	stalk-s
#0	0	0	0	0	L	4	0	0	0	1	1	0	0
#1	0	0	0	0	L	4	0	0	0	1	1	0	0
#2	0	0	0	0	L	4	0	0	0	10	1	0	0
#3	0	0	0	0	L	4	0	0	0	5	1	0	0
#4	0	0	0	0	L	4	0	0	0	10	1	0	0
#5	0	0	0	0	L	4	0	0	0	5	1	0	0
#6	0	0	0	0	L	4	0	0	0	10	1	0	0
#7	0	0	0	0	L	4	0	0	0	10	1	0	0
#8	0	0	0	0	L	4	0	0	0	10	1	0	0
#9	0	0	0	0	L	4	0	0	0	10	1	0	0
#10	0	0	0	0	L	4	0	0	0	10	1	0	0
#11	0	0	0	0	L	4	0	0	0	10	1	0	0
#12	0	0	0	0	L	4	0	0	0	10	1	0	0
#13	0	0	0	0	L	4	0	0	0	10	1	0	0
#14	0	0	0	0	L	4	0	0	0	10	1	0	0
#15	0	0	0	0	L	4	0	0	0	10	1	0	0
#16	0	0	0	0	L	4	0	0	0	10	1	0	0
#17	0	0	0	0	L	4	0	0	0	10	1	0	0
#18	0	0	0	0	L	4	0	0	0	10	1	0	0
#19	0	0	0	0	L	4	0	0	0	10	1	0	0
#20	0	0	0	0	L	4	0	0	0	10	1	0	0
#21	0	0	0	0	L	4	0	0	0	10	1	0	0
#22	0	0	0	0	L	4	0	0	0	10	1	0	0
#23	0	0	0	0	L	4	0	0	0	10	1	0	0
#24	0	0	0	0	L	4	0	0	0	10	1	0	0
#25	0	0	0	0	L	4	0	0	0	10	1	0	0
#26	0	0	0	0	L	4	0	0	0	10	1	0	0
#27	0	0	0	0	L	4	0	0	0	10	1	0	0
#28	0	0	0	0	L	4	0	0	0	10	1	0	0
#29	0	0	0	0	L	4	0	0	0	10	1	0	0
#30	0	0	0	0	L	4	0	0	0	10	1	0	0

Figure 2: Imported dataset in JNN environment

Our task was to predict the result belongs based on the 22 input variables. We conducted a series of tests in order to establish the number of hidden layers and the number of neurons in each hidden layer. Our tests give us that the best results are obtained with two hidden layers. We used a sample of (8,421 records): 5624 training samples and 2500 validating samples. The network structure was found on a trial and error basis (as seen in Figure 3). We started with a small network and gradually increased its size. Finally, we found that the best results are obtained for a network with the following structure: 22I-2H-1O, i.e. 22 input neurons, 2 hidden layers with (3x1) neurons, and an output layer with 1 neuron. For this study we used Just Neural Network (JNN)[58]. We trained the network for 101 epochs (as shown in Figure 4) on a regular computer with 4 GB of RAM memory under the Windows 10 operating system. We get accuracy of 100%. Figure 5 shows Parameters of the proposed ANN model. Figure 6 shows the factors, their importance and relative importance that affect the mushroom artificial Neural Model using Just NN environment. Figure 7 outlines the detail of the proposed ANN model.

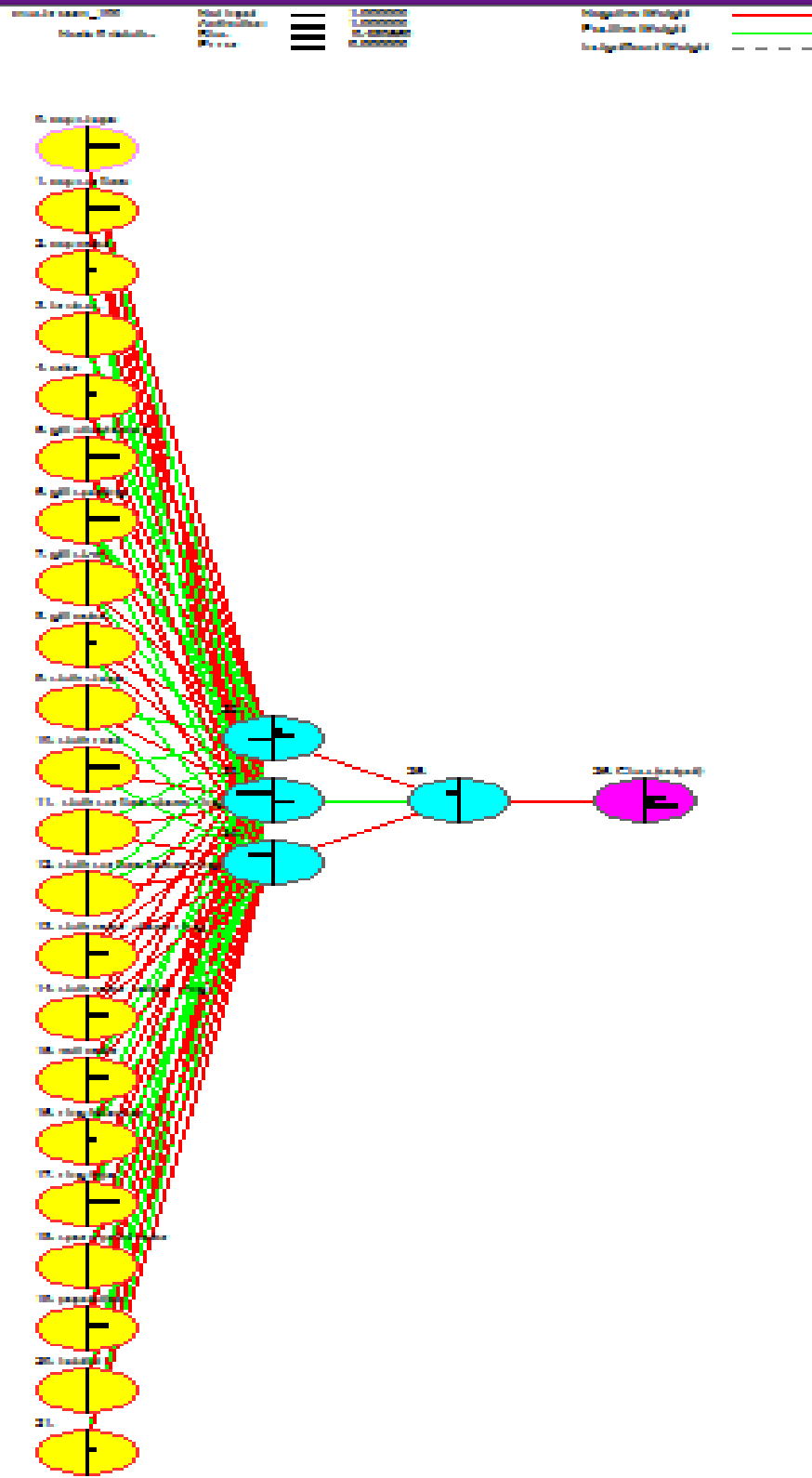


Figure 3: Structure of the proposed ANN model

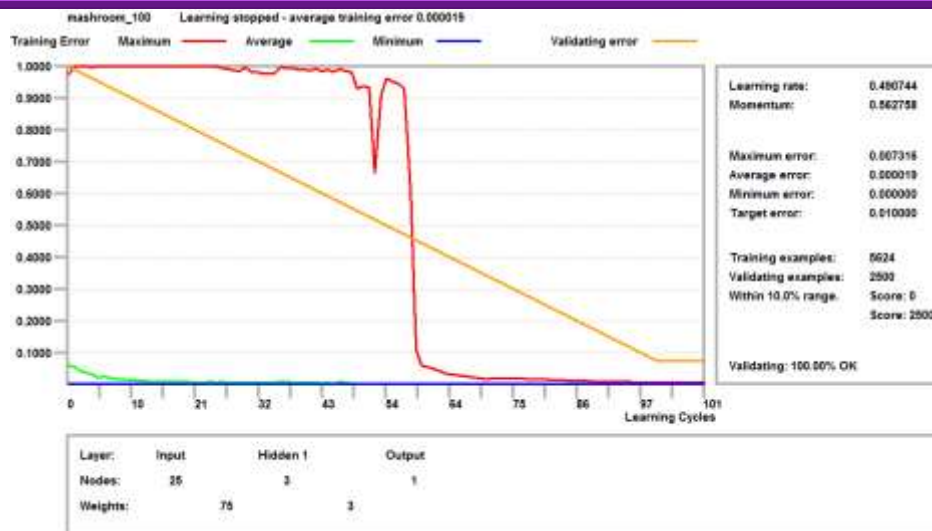


Figure 4: Training and validating the ANN model

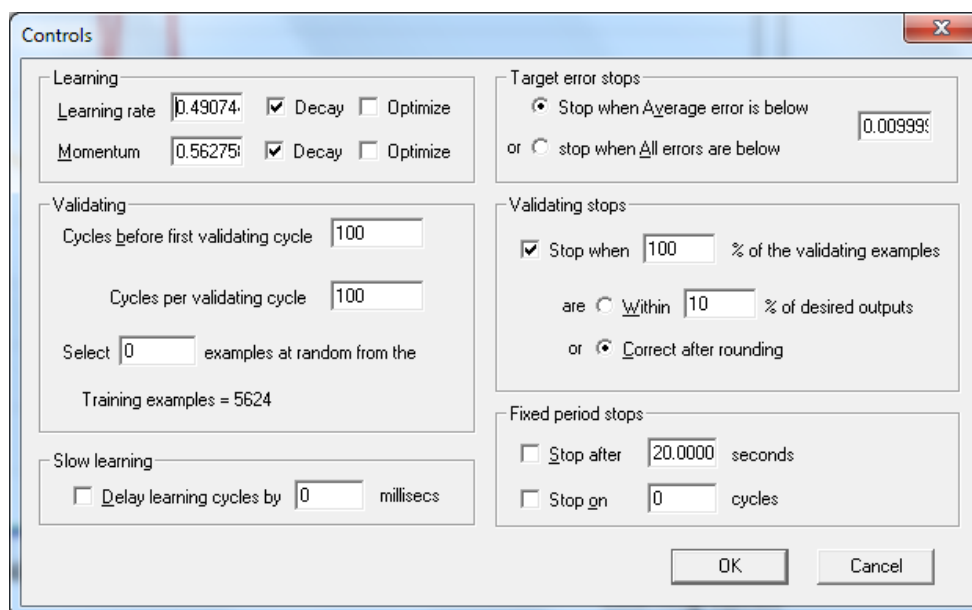


Figure 5: Parameters of the proposed ANN model



Figure 6: Most influential features in the dataset

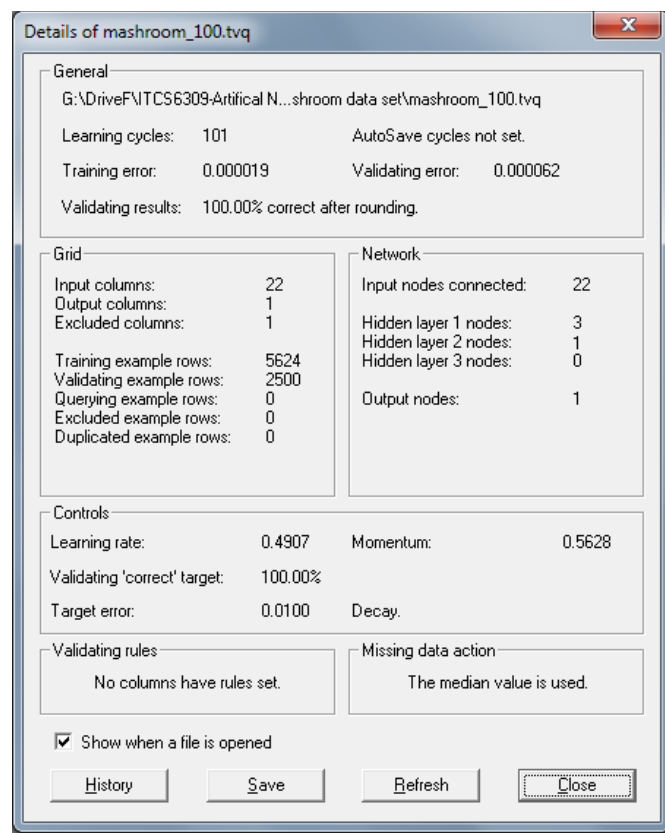


Figure 7: Details of the proposed ANN model

5. CONCLUSION

In This paper, we used the prediction power of a neural network to classify whether a mushroom is edible or poisonous. Our network achieved an accuracy of 100%. We used the JustNN environment for building the network that was a feed forward Multi-Layer Perceptron with one input layer, two hidden layers and one output layer. The average predictability rate was 100% for Prediction of Whether the Mushroom is Edible or Poisonous.

References

1. Haas EM, James P. (2009). *More Vegetables, Please!: Delicious Recipes for Eating Healthy Foods Each & Every Day*. Oakland, California: New Harbinger Publications. p. 22. ISBN 978-1-57224-590-7.
2. "Production of Cultivated Edible Mushroom in China With Emphasis on *Lentinula edodes* - isms.biz". isms.biz.
3. "Poland: The world's largest mushroom exporter". Fresh Plaza. 8 April 2020.
4. Metzler V, Metzler S (1992). *Texas Mushrooms: a Field Guide*. Austin, Texas: University of Texas Press. p. 37. ISBN 0-292-75125-7.
5. Abu Nada, A. M., et al. (2020). "Age and Gender Prediction and Validation Through Single User Images Using CNN." *International Journal of Academic Engineering Research (IJAEER)* 4(8): 21-24.
6. Abu Nada, A. M., et al. (2020). "Arabic Text Summarization Using AraBERT Model Using Extractive Text Summarization Approach." *International Journal of Academic Information Systems Research (IJASIR)* 4(8): 6-9.
7. Abu-Saqer, M. M., et al. (2020). "Type of Grapefruit Classification Using Deep Learning." *International Journal of Academic Information Systems Research (IJASIR)* 4(1): 1-5.
8. Afana, M., et al. (2018). "Artificial Neural Network for Forecasting Car Mileage per Gallon in the City." *International Journal of Advanced Science and Technology* 124: 51-59.
9. Al Barsh, Y. I., et al. (2020). "MPG Prediction Using Artificial Neural Network." *International Journal of Academic Information Systems Research (IJASIR)* 4(11): 7-16.
10. Alajrami, E., et al. (2019). "Blood Donation Prediction using Artificial Neural Network." *International Journal of Academic Engineering Research (IJAEER)* 3(10): 1-7.
11. Alajrami, E., et al. (2020). "Handwritten Signature Verification using Deep Learning." *International Journal of Academic Multidisciplinary Research (IJAMR)* 3(12): 39-44.
12. Al-Araj, R. S. A., et al. (2020). "Classification of Animal Species Using Neural Network." *International Journal of Academic Engineering Research (IJAEER)* 4(10): 23-31.
13. Al-Atrash, Y. E., et al. (2020). "Modeling Cognitive Development of the Balance Scale Task Using ANN." *International Journal of Academic Information Systems Research (IJASIR)* 4(9): 74-81.
14. Alghoul, A., et al. (2018). "Email Classification Using Artificial Neural Network." *International Journal of Academic Engineering Research (IJAEER)* 2(11): 8-14.
15. Al-Kahlout, M. M., et al. (2020). "Neural Network Approach to Predict Forest Fires using Meteorological Data." *International Journal of Academic Engineering Research (IJAEER)* 4(9): 68-72.
16. Alkronz, E. S., et al. (2019). "Prediction of Whether Mushroom is Edible or Poisonous Using Back-propagation Neural Network." *International Journal of Academic and Applied Research (IJAAAR)* 3(2): 1-8.
17. Al-Madhoun, O. S. E.-D., et al. (2020). "Low Birth Weight Prediction Using JNN." *International Journal of Academic Health and Medical Research (IJAHMR)* 4(11): 8-14.
18. Al-Massri, R., et al. (2018). "Classification Prediction of SBRCs Cancers Using Artificial Neural Network." *International Journal of Academic Engineering Research (IJAEER)* 2(11): 1-7.
19. Al-Mobayed, A. A., et al. (2020). "Artificial Neural Network for Predicting Car Performance Using JNN." *International Journal of Engineering and Information Systems (IJEIS)* 4(9): 139-145.
20. Al-Mubayyed, O. M., et al. (2019). "Predicting Overall Car Performance Using Artificial Neural Network." *International Journal of Academic and Applied Research (IJAAAR)* 3(1): 1-5.
21. Alshawwa, I. A., et al. (2020). "Analyzing Types of Cherry Using Deep Learning." *International Journal of Academic Engineering Research (IJAEER)* 4(1): 1-5.
22. Al-Shawwa, M., et al. (2018). "Predicting Temperature and Humidity in the Surrounding Environment Using Artificial Neural Network." *International Journal of Academic Pedagogical Research (IJAPR)* 2(9): 1-6.
23. Ashqar, B. A., et al. (2019). "Plant Seedlings Classification Using Deep Learning." *International Journal of Academic Information Systems Research (IJASIR)* 3(1): 7-14.
24. Bakr, M. A. H. A., et al. (2020). "Breast Cancer Prediction using JNN." *International Journal of Academic Information Systems Research (IJASIR)* 4(10): 1-8.
25. Barhoom, A. M., et al. (2019). "Predicting Titanic Survivors using Artificial Neural Network." *International Journal of Academic Engineering Research (IJAEER)* 3(9): 8-12.
26. Belbeisi, H. Z., et al. (2020). "Effect of Oxygen Consumption of Thylakoid Membranes (Chloroplasts) From Spinach after Inhibition Using JNN." *International Journal of Academic Health and Medical Research (IJAHMR)* 4(11): 1-7.
27. Dalfa, M. A., et al. (2019). "Tic-Tac-Toe Learning Using Artificial Neural Networks." *International Journal of Engineering and Information Systems (IJEIS)* 3(2): 9-19.
28. Dawood, K. J., et al. (2020). "Artificial Neural Network for Mushroom Prediction." *International Journal of Academic Information Systems Research (IJASIR)* 4(10): 9-17.
29. Dheir, I. M., et al. (2020). "Classifying Nuts Types Using Convolutional Neural Network." *International Journal of Academic Information Systems Research (IJASIR)* 3(12): 12-18.
30. El-Khatib, M. J., et al. (2019). "Glass Classification Using Artificial Neural Network." *International Journal of Academic Pedagogical Research (IJAPR)* 3(2): 25-31.
31. El-Mahelawi, J. K., et al. (2020). "Tumor Classification Using Artificial Neural Networks." *International Journal of Academic Engineering Research (IJAEER)* 4(11): 8-15.
32. El-Mashharawi, H. Q., et al. (2020). "Grape Type Classification Using Deep Learning." *International Journal of Academic Engineering Research (IJAEER)* 3(12): 41-45.
33. Elzamy, A., et al. (2015). "Classification of Software Risks with Discriminant Analysis Techniques in Software planning Development Process." *International Journal of Advanced Science and Technology* 81: 35-48.
34. Elzamy, A., et al. (2015). "Predicting Software Analysis Process Risks Using Linear Stepwise Discriminant Analysis: Statistical Methods." *Int. J. Adv. Inf. Sci. Technol* 38(38): 108-115.
35. Elzamy, A., et al. (2017). "Predicting Critical Cloud Computing Security Issues using Artificial Neural Network (ANNs) Algorithms in Banking Organizations." *International Journal of Information Technology and Electrical Engineering* 6(2): 40-45.
36. Habib, N. S., et al. (2020). "Presence of Amphibian Species Prediction Using Features Obtained from GIS and Satellite Images." *International Journal of Academic and Applied Research (IJAAAR)* 4(11): 13-22.
37. Harz, H. H., et al. (2020). "Artificial Neural Network for Predicting Diabetes Using JNN." *International Journal of Academic Engineering Research (IJAEER)* 4(10): 14-22.
38. Hassanein, R. A. A., et al. (2020). "Artificial Neural Network for Predicting Workplace Absenteeism." *International Journal of Academic Engineering Research (IJAEER)* 4(9): 62-67.
39. Heriz, H. H., et al. (2018). "English Alphabet Prediction Using Artificial Neural Networks." *International Journal of Academic Pedagogical Research (IJAPR)* 2(11): 8-14.
40. Jaber, A. S., et al. (2020). "Evolving Efficient Classification Patterns in Lymphography Using EasyNN." *International Journal of Academic Information Systems Research (IJASIR)* 4(9): 66-73.
41. Kashf, D. W. A., et al. (2018). "Predicting DNA Lung Cancer using Artificial Neural Network." *International Journal of Academic Pedagogical Research (IJAPR)* 2(10): 6-13.
42. Khalil, A. J., et al. (2019). "Energy Efficiency Predicting using Artificial Neural Network." *International Journal of Academic Pedagogical Research (IJAPR)* 3(9): 1-8.
43. Kweik, O. M. A., et al. (2020). "Artificial Neural Network for Lung Cancer Detection." *International Journal of Academic Engineering Research (IJAEER)* 4(11): 1-7.
44. Maghari, A. M., et al. (2020). "Books' Rating Prediction Using Just Neural Network." *International Journal of Engineering and Information Systems (IJEIS)* 4(10): 17-22.
45. Mettleq, A. S. A., et al. (2020). "Mango Classification Using Deep Learning." *International Journal of Academic Engineering Research (IJAEER)* 3(12): 22-29.
46. Metwally, N. F., et al. (2018). "Diagnosis of Hepatitis Virus Using Artificial Neural Network." *International Journal of Academic Pedagogical Research (IJAPR)* 2(11): 1-7.
47. Mohammed, G. R., et al. (2020). "Predicting the Age of Abalone from Physical Measurements Using Artificial Neural Network." *International Journal of Academic and Applied Research (IJAAAR)* 4(11): 7-12.
48. Musleh, M. M., et al. (2019). "Predicting Liver Patients using Artificial Neural Network." *International Journal of Academic Information Systems Research (IJASIR)* 3(10): 1-11.
49. Oriban, A. J. A., et al. (2020). "Antibiotic Susceptibility Prediction Using JNN." *International Journal of Academic Information Systems Research (IJASIR)* 4(11): 1-6.
50. Qwaider, S. R., et al. (2020). "Artificial Neural Network Prediction of the Academic Warning of Students in the Faculty of Engineering and Information Technology in Al-Azhar University-Gaza." *International Journal of Academic Information Systems Research (IJASIR)* 4(8): 16-22.
51. Sadek, R. M., et al. (2019). "Parkinson's Disease Prediction Using Artificial Neural Network." *International Journal of Academic Health and Medical Research (IJAHMR)* 3(1): 1-8.
52. Salah, M., et al. (2018). "Predicting Medical Expenses Using Artificial Neural Network." *International Journal of Engineering and Information Systems (IJEIS)* 2(20): 11-17.
53. Salman, F. M., et al. (2020). "COVID-19 Detection using Artificial Intelligence." *International Journal of Academic Engineering Research (IJAEER)* 4(3): 18-25.
54. Samra, M. N. A., et al. (2020). "ANN Model for Predicting Protein Localization Sites in Cells." *International Journal of Academic and Applied Research (IJAAAR)* 4(9): 43-50.
55. Shawarib, M. Z. A., et al. (2020). "Breast Cancer Diagnosis and Survival Prediction Using JNN." *International Journal of Engineering and Information Systems (IJEIS)* 4(10): 23-30.
56. Zaqout, I., et al. (2015). "Predicting Student Performance Using Artificial Neural Network: in the Faculty of Engineering and Information Technology." *International Journal of Hybrid Information Technology* 8(2): 221-228.

57. Choy, Christopher B., et al. "3d-r2n2: A unified approach for single and multi-view 3d object reconstruction." European conference on computer vision. Springer, Cham, 2016.
58. French, Jordan (2016). "The time traveller's CAPM". *Investment Analysts Journal*. 46 (2): 81–96. doi:10.1080/10293523.2016.1255469. S2CID 157962452.
59. Schechner, Sam (15 June 2017). "Facebook Boosts A.I. to Block Terrorist Propaganda". *Wall Street Journal*. ISSN 0099-9660. Retrieved 16 June 2017.
60. Ganesan, N (2010). "Application of Neural Networks in Diagnosing Cancer Disease Using Demographic Data". *International Journal of Computer Applications*. 1 (26): 81–97. Bibcode:2010IJCA....1z..81G. doi:10.5120/476-783.
61. Bottaci, Leonardo (1997). "Artificial Neural Networks Applied to Outcome Prediction for Colorectal Cancer Patients in Separate Institutions" (PDF). *Lancet. The Lancet*. 350 (9076): 469–72. doi:10.1016/S0140-6736(96)11196-X. PMID 9274582. S2CID 18182063. Archived from the original (PDF) on 23 November 2018. Retrieved 2 May 2012.
62. Alizadeh, Elaheh; Lyons, Samanthe M; Castle, Jordan M; Prasad, Ashok (2016). "Measuring systematic changes in invasive cancer cell shape using Zernike moments". *Integrative Biology*. 8 (11): 1183–1193. doi:10.1039/C6IB00100A. PMID 27735002.
63. Lyons, Samanthe (2016). "Changes in cell shape are correlated with metastatic potential in murine". *Biology Open*. 5 (3): 289–299. doi:10.1242/bio.013409. PMC 4810736. PMID 26873952.
64. Nabian, Mohammad Amin; Meidani, Hadi (28 August 2017). "Deep Learning for Accelerated Reliability Analysis of Infrastructure Networks". *Computer-Aided Civil and Infrastructure Engineering*. 33 (6): 443–458.
65. Nabian, Mohammad Amin; Meidani, Hadi (2018). "Accelerating Stochastic Assessment of Post-Earthquake Transportation Network Connectivity via Machine-Learning-Based Surrogates". *Transportation Research Board 97th Annual Meeting*.
66. Díaz, E.; Brotons, V.; Tomás, R. (September 2018). "Use of artificial neural networks to predict 3-D elastic settlement of foundations on soils with inclined bedrock". *Soils and Foundations*. 58 (6): 1414–1422.
67. Ermini, Leonardo; Catani, Filippo; Casagli, Nicola (2005). "Artificial Neural Networks applied to landslide susceptibility assessment". *Geomorphology. Geomorphological hazard and human impact in mountain environments*. 66 (1): 327–343. Bibcode:2005Geom...66..327E. doi:10.1016/j.geomorph.2004.09.025.
68. Nix, R.; Zhang, J. (2017). "Classification of Android apps and malware using deep neural networks". 2017 International Joint Conference on Neural Networks (IJCNN): 1871–1878.
69. Peres, D. J.; Iuppa, C.; Cavallaro, L.; Cancelliere, A.; Foti, E. (1 October 2015). "Significant wave height record extension by neural networks and reanalysis wind data". *Ocean Modelling*. 94: 128–140. Bibcode:2015OcMod..94..128.
70. Dwarakish, G. S.; Rakshith, Shetty; Natesan, Usha (2013). "Review on Applications of Neural Network in Coastal Engineering". *Artificial Intelligent Systems and Machine Learning*. 5 (7): 324–331.
71. UCI Machine Learning repository (<https://archive.ics.uci.edu/ml/datasets.html>)
72. EasyNN Tool.